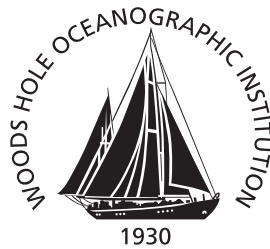


# Woods Hole Oceanographic Institution



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## Turbulence in the Coastal Environment during HYCODE

by

J. J. Fredericks  
John H. Trowbridge

March 2004

### Technical Report

Funding was provided by the Office of Naval Research under Contract No. N00014-99-1-0213.

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WHOI-2004-05

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**W. Rockwell Geyer, Chair**

Department of Applied Ocean Physics and Engineering

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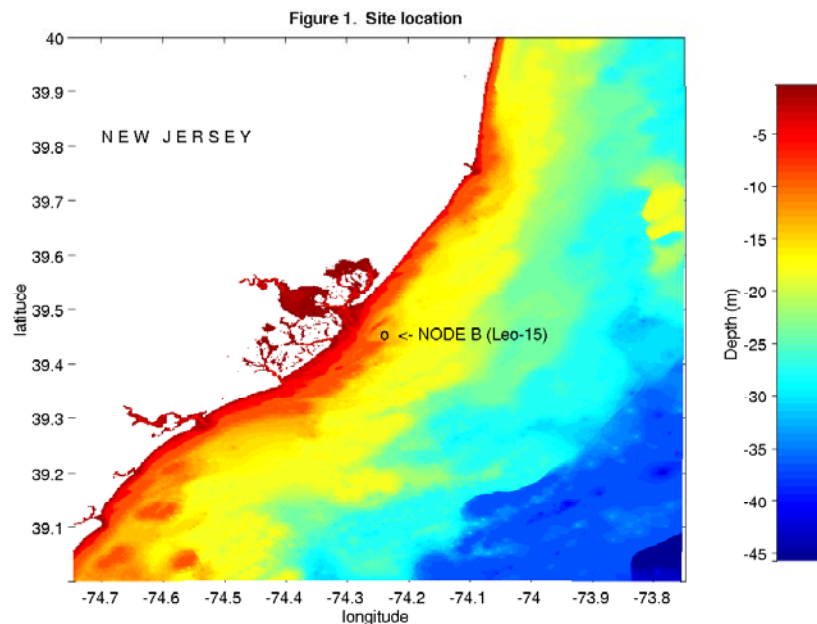
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## I. INTRODUCTION

A tall tripod (also termed the Trowbridge tripod) equipped with two acoustic Doppler velocimeters (ADV), which produce high quality measurements of three-dimensional velocity, was deployed from late July through early December of 2000, and again from late June through early August, 2001. The tripod was deployed at a water depth of approximately 15 m off the coast of New Jersey near Node B of the Leo-15 site (see Figure 1). Sensors were co-located in a fashion so as to be able to use a differencing technique to remove the waves to provide good estimates of Reynolds stress. Thermistors were located within several centimeters of the velocity sample volume to provide simultaneously sampled estimates of turbulent temperature variance and vertical temperature flux. One of the ADVs was equipped with a pressure sensor and temperature sensor. A wave and tide gauge was placed on the tripod platform. For the 2001 deployment, a single beam acoustic Doppler velocity sensor (DopBeam) was added to measure high frequency vertical velocity variance and echo intensity within the bottom boundary layer.

A second tripod (also termed the Agrawal tripod) was deployed within 100 meters of the tall tripod and was equipped with an array of LISST sensors, including a LISST-ST, providing settling velocity, and an MSCAT, providing particle size within 10 cm of the bottom. It is beyond the scope of this report to discuss these data and instruments.

The purpose of this report is to document the instrumentation and deployment of the tripods. The data collected from the instruments on the Trowbridge tripod are documented by including a description of the processing, time-series summaries, preliminary analyses and formats of the raw and processed data archives.



**Table 1. Sensor information for Deployment I**

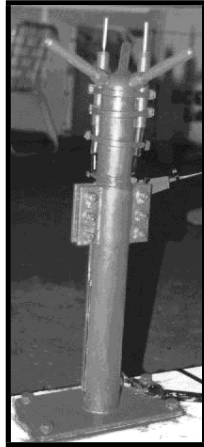
ADV OPB	SN/5026
ADV OPA	SN/B084H
Seagauge 7/00 - 9/00	SG#41/SB 041163
Seagauge 9/00 - 12/00	SG#43/SB 041166

**Table 2. Sensor information for Deployment II**

<b>Instrument</b>	<b>Sensor ID</b>
ADV OPB	SN/5026
ADV OPA	SN/B084H
Seagauge 6/01-8/01	SG#48/SB 041425

## II. INSTRUMENTATION

Two SonTek<sup>1</sup> ADV Ocean Probes (ADV OP<sub>A</sub> and ADV OP<sub>B</sub>) were mounted on a 5 meter tall tripod to measure horizontal and vertical velocity. The ADVs were simultaneously sampled at 5 Hz. The data were logged on a TattleTale<sup>2</sup> 6-1M for approximately 30 minutes beginning 15 minutes before the start of each hour. Table 1 shows instrument serial numbers.



During the 2000 field program, five YSI<sup>3</sup> thermistors were strapped to each ADV and simultaneously logged at 5 Hz, as shown in Figure 2. YSI1 was mounted on the tripod platform, YSI3 and YSI4 on ADV OP<sub>A</sub>, and YSI2 and YSI5 on ADV OP<sub>B</sub>. The thermistor heights of YSI1-YSI5 were 4.2, 0.70, 3.4, 3.4 and 0.70 meters above bottom, respectively. The sampling volume for each of the thermistors mounted on ADV OP<sub>B</sub> was approximately 10 cm below the velocity sampling volume of ADV OP<sub>B</sub> and those on ADV OP<sub>A</sub> were 10 cm above the velocity sampling volume of ADV OP<sub>A</sub>. The thermistors were not recorded during the 2001 field program. Sampling volumes of each ADV are shown in Figures 3a and 3b.

**Figure 2.** ADV with YSIs

ADV OP<sub>A</sub> was equipped with a strain-gauge pressure sensor, compass, tilt meter and temperature sensor, which were housed in the probe casing. The probes were coated with two to three coats of antifoulant paint, except the transducer faces, which received only one coat. The tripod legs and support channel were coated with zinc oxide antifoulant to minimize flow disturbance from the structure. Tall tripod instrumentation is depicted in Figures 3a and 3b. A picture of the 2000 tall tripod instrument configuration is shown in Figure 4a along with a picture of the Agrawal tripod (Figure 4b). The ADVs were logged in the instrument coordinate system, with +X aligned to point directly toward the tripod center. (See Figures 5a - 5c.) The velocity range for each sensor was set at  $\pm 200$  cm/s, except for the ADV OP<sub>A</sub> during deployment II, which was inadvertently set at  $\pm 500$  cm/s. A static salinity (32 PSU) and temperature (12°C) were defined, for the ADV preliminary sound-speed computations.

During 2001, a SonTek, single beam acoustic velocity sensor, also called a DopBeam, was deployed to measure vertical velocity at 375 Hz, recording 125 1.2 cm bins below the sensor. The DopBeam was mounted approximately 2 m from each leg on a channel (5 cm x 13 cm) at 1.3 meters above bottom (Figure 3b).

A SBE 26 Seagauge<sup>4</sup> Wave and Tide Recorder was strapped to the tripod platform to log pressure, temperature and conductivity for each deployment. Tide data was recorded every 5 minutes for Deployment I and every 2 minutes for Deployment II, as well as wave data every three hours for each deployment.

The array of sensors on the Agrawal tripod were provided by Sequoia Scientific<sup>5</sup>.

<sup>1</sup>SonTek, Inc., San Diego, CA 92121

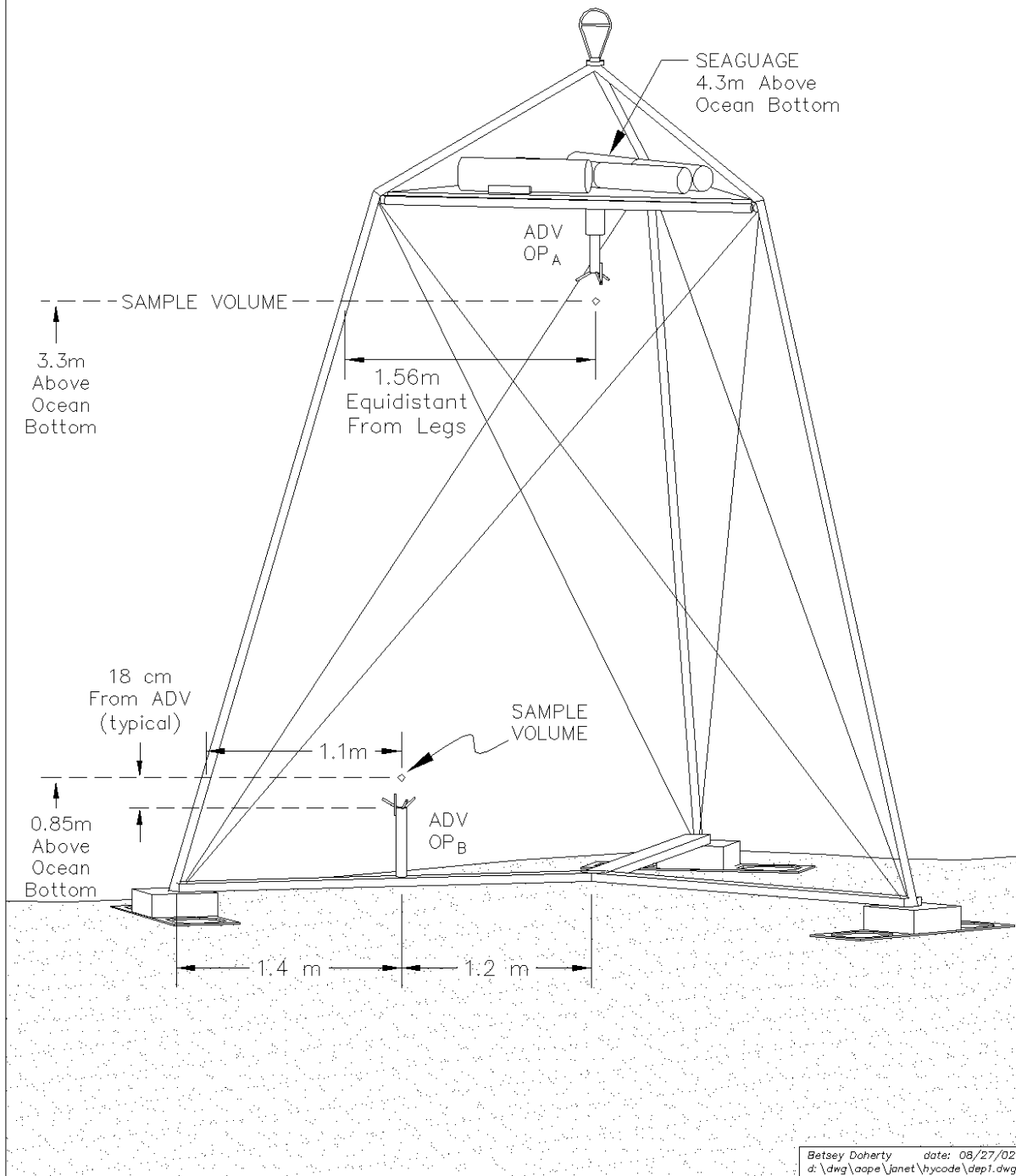
<sup>2</sup>Onset Computer Corporation, Pocasset, MA 02559-3450

<sup>3</sup>YSI Inc., Yellow Springs, OH 45387

<sup>4</sup>Seabird Electronics Inc., Bellevue, WA 98005

<sup>5</sup>Sequoia Scientific, Inc., Bellevue, WA 98005

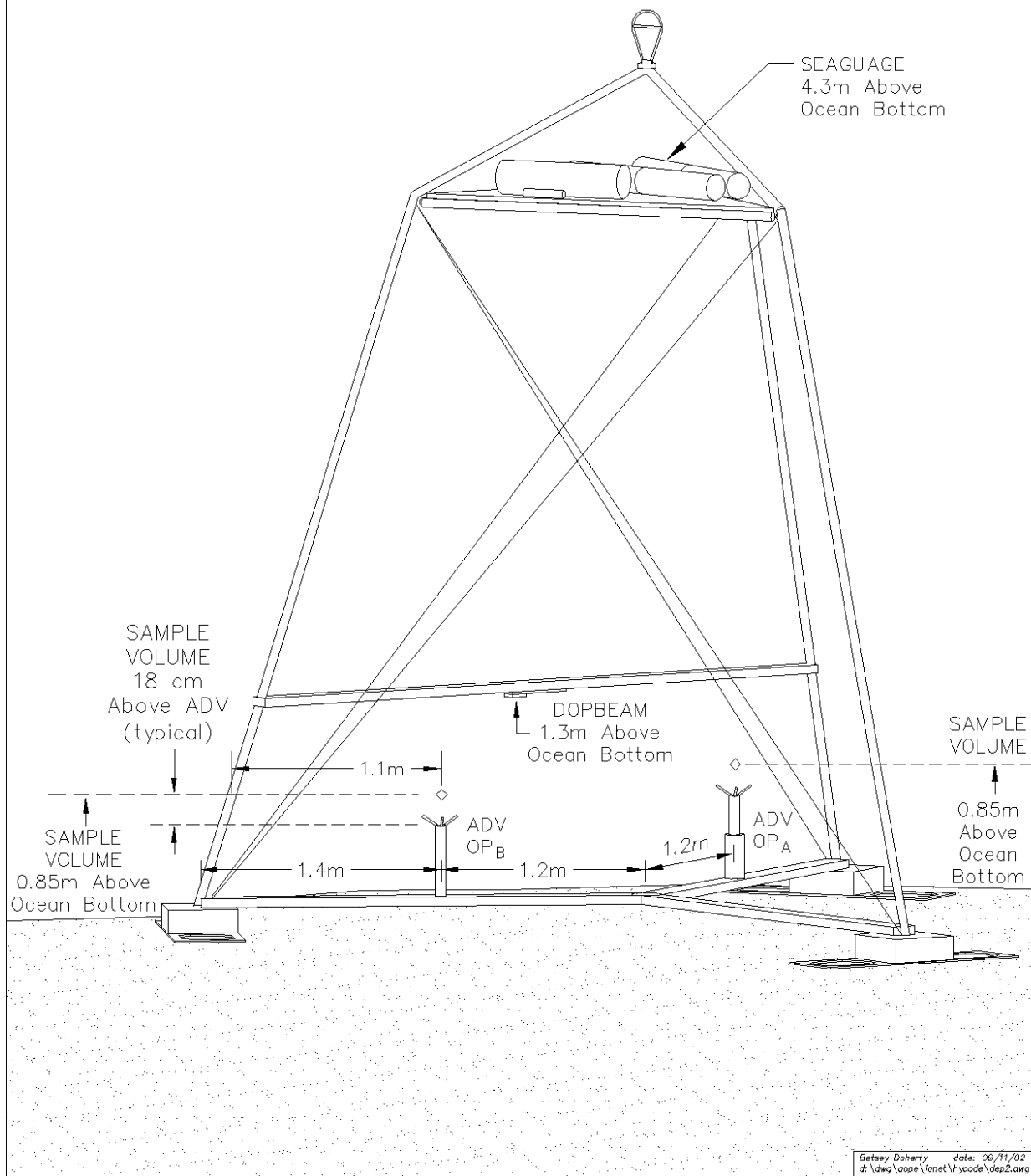
## HYCODE Tripod Deployment I



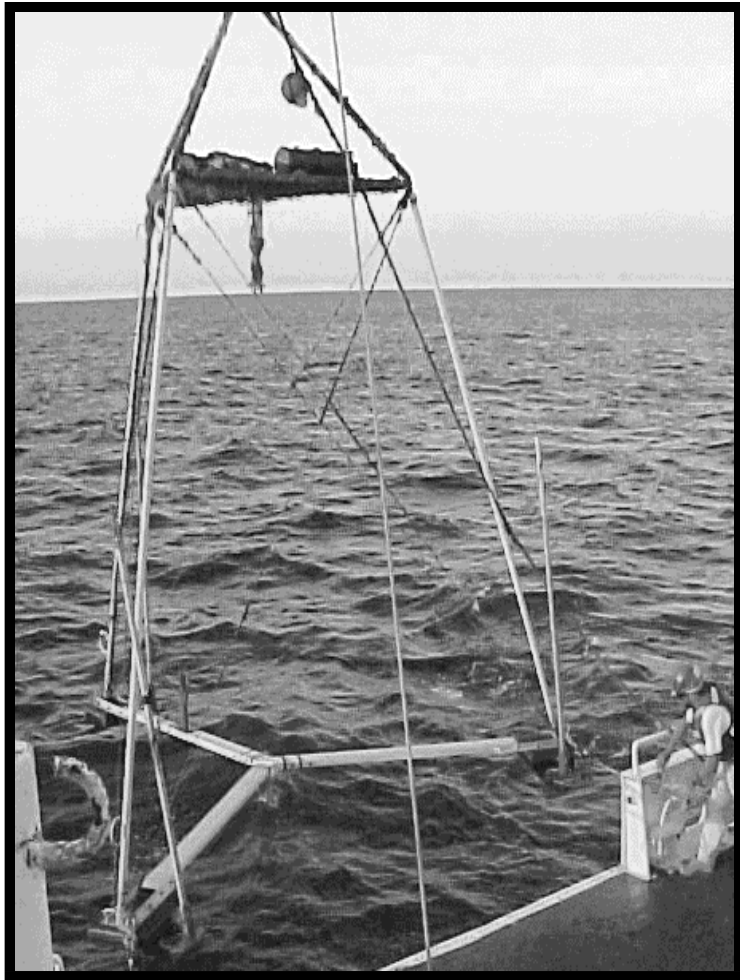
**Figure 3a.** Deployment I: 7/24/2000 - 12/02/2000 Instrumentation



## HYCODE Tripod Deployment II

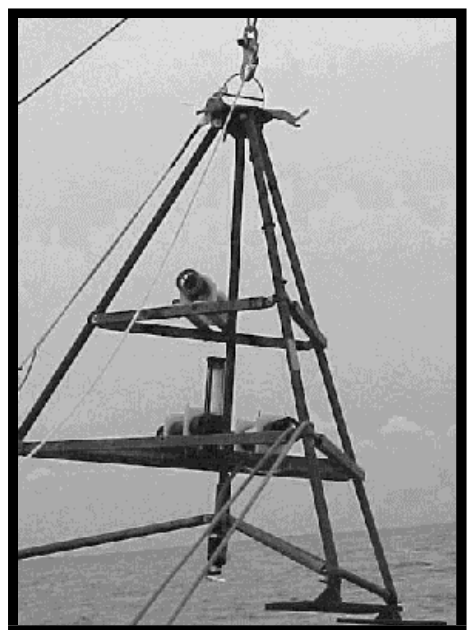


**Figure 3b.** Deployment II: 6/20/2001 - 8/06/2001 Instrumentation



**Figure 4a.** Trowbridge tripod - 2000.

**Figure 4b.** Agrawal tripod - 2000



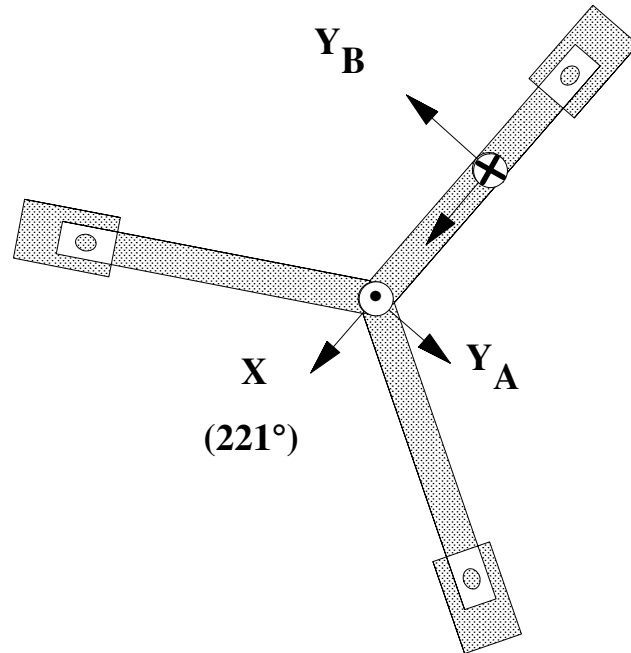
### III. DEPLOYMENT

The experiment was conducted in 15 meters of water near Node B of the LEO-15 site off the coast of New Jersey at Little Egg Inlet (Figure 1). In 2000, the tripods were deployed from late July through early December, with a turn-around deployment in September. The tripods were again deployed from mid-June through early August, 2001. The orientation of the tall tripod, showing ADV instrument coordinates relative to North (true), is depicted for each deployment in Figures 5a - 5c. Each deployment site is shown relative to Node B, along with the general area of a near-by mudpatch (Figure 6).

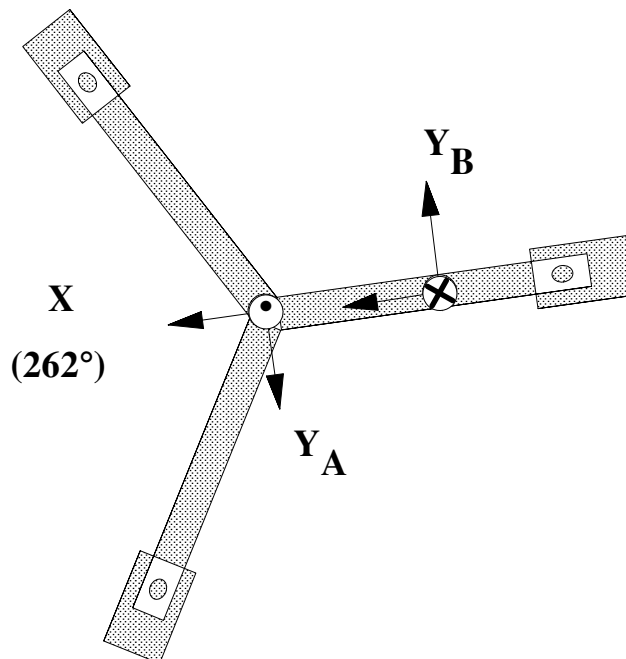
The first deployment was on July 24, 2000, from RV/Endeavor (EN-342) at 19:29 UTM. The Trowbridge tripod and the Agrawal tripod were deployed at  $39^{\circ} 27.38' \text{ N}$ ,  $74^{\circ} 14.31' \text{ W}$  and at  $39^{\circ} 27.40' \text{ N}$ ,  $74^{\circ} 14.24' \text{ W}$ , respectively. On July 27, the tripods were anchored with 15 ft. pipes jettied into the seafloor. On September 13, divers removed the anchors from the tripods and recovered the Agrawal tripod aboard the RV/Arabella. During RV/Endeavor EN-344, the tall tripod was recovered (Figure 4a) on September 15, 22:45 UTM, and serviced for redeployment on September 16, 14:35 UTM at  $39^{\circ} 27.30' \text{ N}$ ,  $74^{\circ} 14.31' \text{ W}$ . The Agrawal tripod was redeployed and anchored to the seafloor from the RV/Arabella on October 11 at  $39^{\circ} 27.39' \text{ N}$ ,  $74^{\circ} 14.12' \text{ W}$ . The tripod anchors were removed on 11/29 (RV/Arabella). And, on December 2, both tripods were recovered aboard the RV/Endeavor (EN-347).

On June 20, 2001, both tripods were again deployed at 10:50 UTM from the RV/Endeavor (EN-356). The Trowbridge tripod and the Agrawal tripod were deployed at 10:50 UTM at  $39^{\circ} 27.39' \text{ N}$ ,  $74^{\circ} 14.31' \text{ W}$  and at  $39^{\circ} 27.40' \text{ N}$ ,  $74^{\circ} 14.24' \text{ W}$ , respectively. On June 22, the tripods were anchored to the seabed. The tripods were recovered at 16:50 UTM on August 6, 2001, during R/V Endeavor Cruise EN-358.

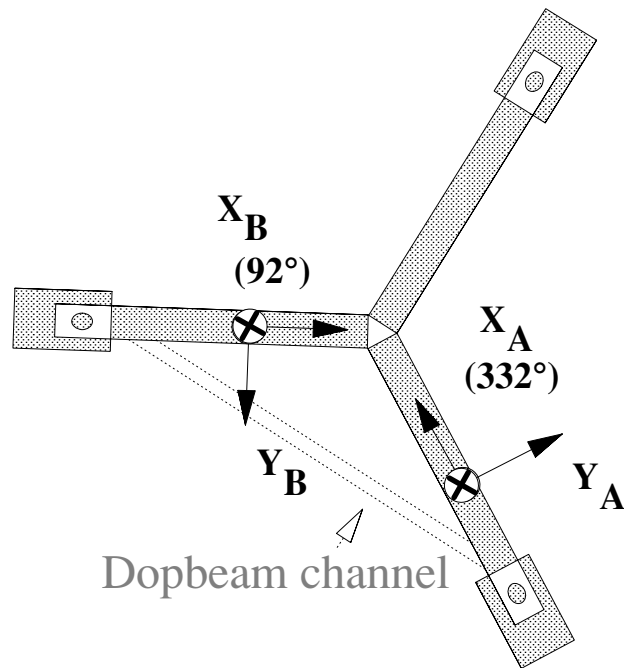
**Figure 5a.** Deployment I: 7/24/2000 - 9/15/2000 - Orientation (degrees from True North)  
 X represents direction in the instrument coordinate system for both ADV Ocean Probes.  
 $Y_A$  &  $Y_B$  represents the Y-direction of ADV OP<sub>A</sub> and ADV OP<sub>B</sub>, respectively.



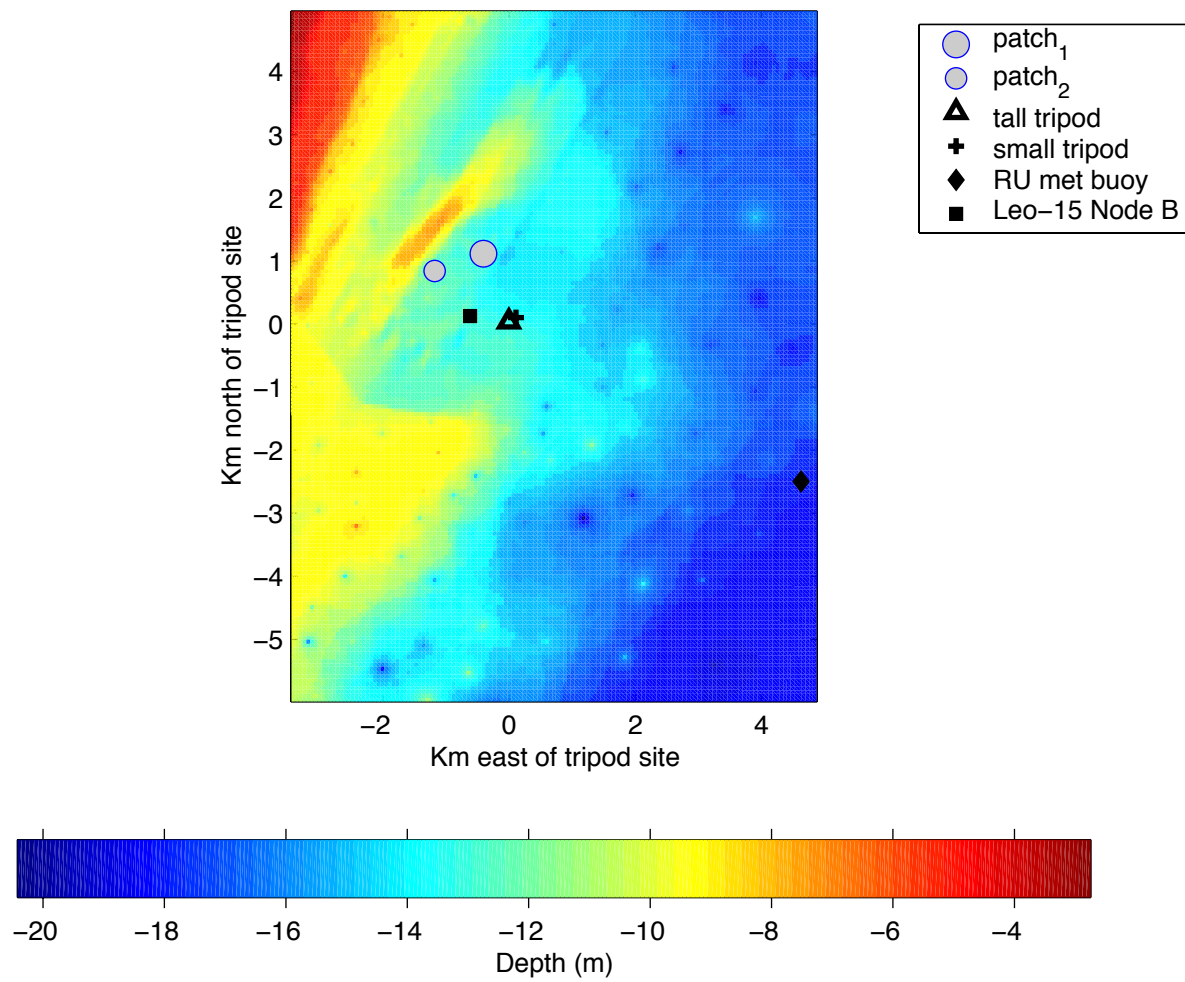
**Figure 5b.** Deployment I: 9/26/2000 - 12/2/2000 - Orientation (degrees from True North)  
 X represents direction in the instrument coordinate system for both ADV Ocean Probes.



**Figure 5c.** Deployment II: 6/16/2001 - 8/6/2001 - Orientation (degrees from True North)



**Figure 6.** Deployment sites. Patch 1 and Patch 2 refer to fine sediment patches (smaller than 4 Phi, Craghan, 1995). Sediments outside of the patches 1 and 2 were generally more coarse.



## IV. DATA PROCESSING

During the 2000 experiment, all sensors on the tall tripod functioned through 11/20/2000, when the battery supply became too low to adequately power the ADVs. For the 2001 deployment, the ADVs only recorded approximately seven days of data (6/20 - 6/26/01), due to hardware failure. The Dopbeam recorded data through the end of July and the Seagauge recorded throughout the 2001 deployment.

### ADV Data

Data were unpacked using Matlab<sup>6</sup> converted to world units and stored in Matlab files of one burst per file. Data formats are documented in Section VII. Using the compass from OP<sub>A</sub>, the data were rotated to north (v) and east (u), true, using a magnetic deviation of 13° W.

Data were masked with NaN when the correlation coefficient of signal strength of a beam was less than 70 as well as when a value was more than four standard deviations from the half-hour burst average.

Velocity data were corrected for sound speed using the Seagauge salinity and pressure and the temperature from the YSI thermistors mounted on each ADV.

The ocean probe, ADV OP<sub>B</sub>, had intermittent problems, which caused loss of ADV data. To remove these bad data, the bursts were evaluated in 151 sample blocks (30 seconds) called minibursts. When the data were noisy, the correlation coefficient of the signal strength did not approach 100% during the affected period. Minibursts having fewer than 67% of the correlation coefficient of signal strengths greater than 90% were masked with NaNs and not included in the processing. Only 10% of data from the July 2000 deployment and 30 % from the September 2000 deployment consisted of bursts which had more than 20% of the burst flagged as bad. 85% of the first deployment and 61% of the second deployment had valid data for more than 98% of the bursts.

Since the maximum velocity range for ADV OP<sub>A</sub> was set to  $\pm 500$  for the 2001 deployment, the noise floor in the horizontal and vertical velocity was about 4 times greater than the noise floor of the OP<sub>B</sub> observations.

---

<sup>6</sup>The Mathworks, Inc., Natick, MA 01760

The wave-induced orbital velocity,  $U_{\text{rms}}$ , was computed as

$$U_{\text{rms}} = \int_{0.05\text{Hz}}^{0.5\text{Hz}} (S_{uu} + S_{vv}) \cdot df$$

where  $S_{uu} + S_{vv}$  represent the spectral density of horizontal velocities.

The mean frequency in the wave band was computed as a weighted mean:

$$F_{\text{bar}} = \frac{\int_{0.05\text{Hz}}^{0.5\text{Hz}} (S_{uu} + S_{vv}) \cdot f \cdot df}{\int_{0.05\text{Hz}}^{0.5\text{Hz}} (S_{uu} + S_{vv}) \cdot df}$$

Wave direction is defined as the direction from eastward with positive being from the north of east and was computed as follows:

$$1/2 \cdot \text{atan} \left[ \frac{\int_{0.05\text{Hz}}^{0.5\text{Hz}} 2 \cdot C_{uv}}{\int_{0.05\text{Hz}}^{0.5\text{Hz}} (S_{uu} - S_{vv})} \right]$$

where  $C_{uv}$  represents the covariance of the horizontal velocities from the spectral estimates.

Significant wave heights, defined as 4 times the standard deviation of the surface displacement, were recorded on the Seagauge, as well as computed from the Sontek pressure and ADV horizontal velocities, using linear wave theory (Dean and Dalrymple, 1991), and integrating in the wave peak, between 0.05 and 0.5 Hz. The various estimates of wave height are compared in Section VI.

Dissipation was computed from the ADV vertical velocities using the model-based procedure described by Trowbridge & Elgar (2001) from valid 30 second mini-bursts. The model was applied between 0.9 Hz and 1.5 Hz, removing noise as determined by the spectral density at frequencies greater than 2 Hz. Estimates were also computed from horizontal velocities and are compared in Section VI.

Estimates of turbulent Reynolds shear stress were computed using the procedure described by Shaw & Trowbridge (2001). Each estimate of stress was computed as  $\langle \Delta V_f' W' \rangle$ , where  $W$  represents the vertical velocity of each ADV and  $\Delta V_f$  represents the differenced horizontal velocity between the sensors.

Signal strength outliers, values greater than 4 times the standard deviation from the mean, were removed from each of the three beams and the three beams were averaged. The standard deviation was computed from the detrended signal strength.



## YSI Data/ Heat Flux

The YSI thermistors and the Seagauge temperature were compared with each other during periods when the water column was well mixed. It became apparent that there was drift in YSI2 and YSI4, so YSI5 is used at 0.8 mab and YSI3 at 3.3 mab.

For the 2000 deployment, the thermistor in the ADV OP<sub>A</sub> was compared to the YSI3 during times when the temperature difference between the two ADVs was less than 0.01 °C. This indicated an offset of 0.057 °C, which was added to the the ADV temperature (temp\_a) in the data summary files (Section VII). The slope and correlation coefficient were 1.0.

As shown in Section VI, temporal lag in the thermistors preclude accurate estimates of  $\langle T'W' \rangle$  and are not presented Section V.

## DopBeam Data

DopBeam data are comprised of the sound signal amplitude, A, and the cosine (C) and sine (S) of the received sound phase, phi(t), where t represents time. The quantity

$$R(t) = \langle Z(t)Z^*(t+\tau) \rangle$$

is computed, where  $Z(t)$  represents  $C(t) + iS(t)$  and  $\tau$  is the interval between acoustic pings,  $*$  denotes the complex conjugate, and  $\langle \rangle$  denotes an average over 40 pings. The time derivative of phi is calculated according to  $d\phi/dt = (1/\tau) \arctan[\text{imag}(R)/\text{real}(R)]$ , and the velocity is calculated from the Doppler relationship  $U = (d\phi/dt)/(2k)$ . Here U is the along-beam velocity and k is the wavenumber of the sound, given by  $k = 2\pi f/c$ , where f is the frequency of the sound and c is the speed of sound, nominally assigned as 1500 m/s. This technique, called pulse-pair processing, resulted in vertical velocity data at approximately 10 Hz.

Data on even hours were stored on one hard drive, while data on odd hours were stored on another. This method of storage was employed since all data could not fit on only one of the 30 GB hard drives and by using alternate disks on write, the risk of failure due to hard disk problems was reduced. Even hour data on 6/21/2001 were inadvertently erased and are not available.

Due to operating system interrupts, each otherwise continuous byte stream was interrupted between 21 and 28 times in the 5 minute burst. These interruptions were detected by noting times when the start of profile flag, 0xffffffff, was not the expected 375 bytes from the last flag. It was assumed that bytes had been dropped in the data stream, and therefore, the data were replaced with a full record of NaNs. For reasons not understood, 10 bursts could not be unpacked and processed: 6/28 16:57, 6/29 13:57, 7/1 15:57, 7/8 15:57, 7/10 4:57, 7/11 21:57, 7/12 5:57, 7/12 15:57, 7/15 9:57, and 7/24 21:57.

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## V. DATA SUMMARIES

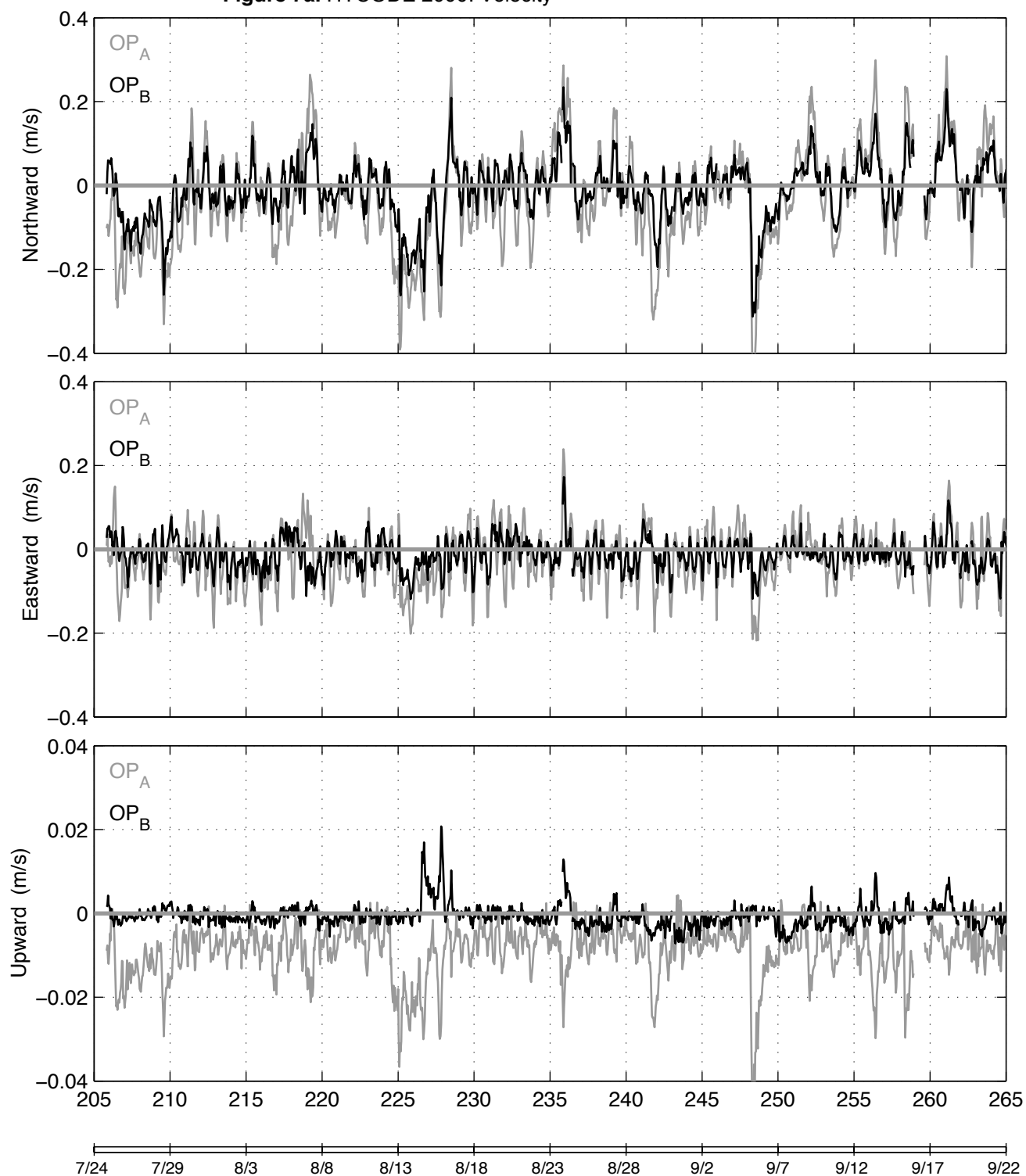
This section includes the burst-averaged time series of the velocity, pressure, temperature and salinity collected during the deployments. Also included are the computed estimates of stress, dissipation (from vertical velocity), significant wave height, bottom orbital velocity, angle of incidence of the waves and wave period. The average acoustic signal is also included as a means to qualitatively determine periods of sediment suspension.

NOTE: The time scale for 2000 differs from that of 2001 in the following timeseries.

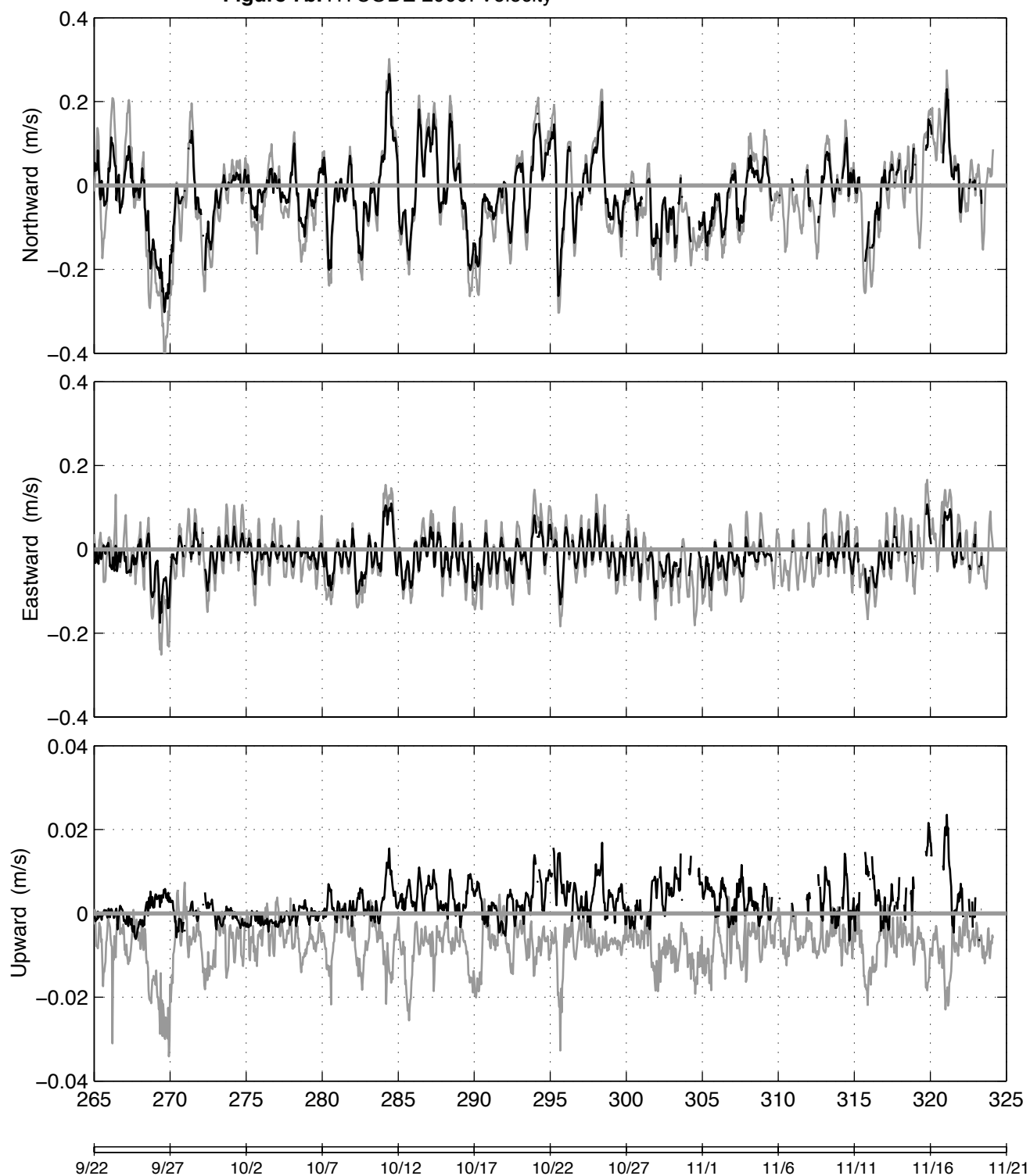
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## **Horizontal and Vertical Velocity**

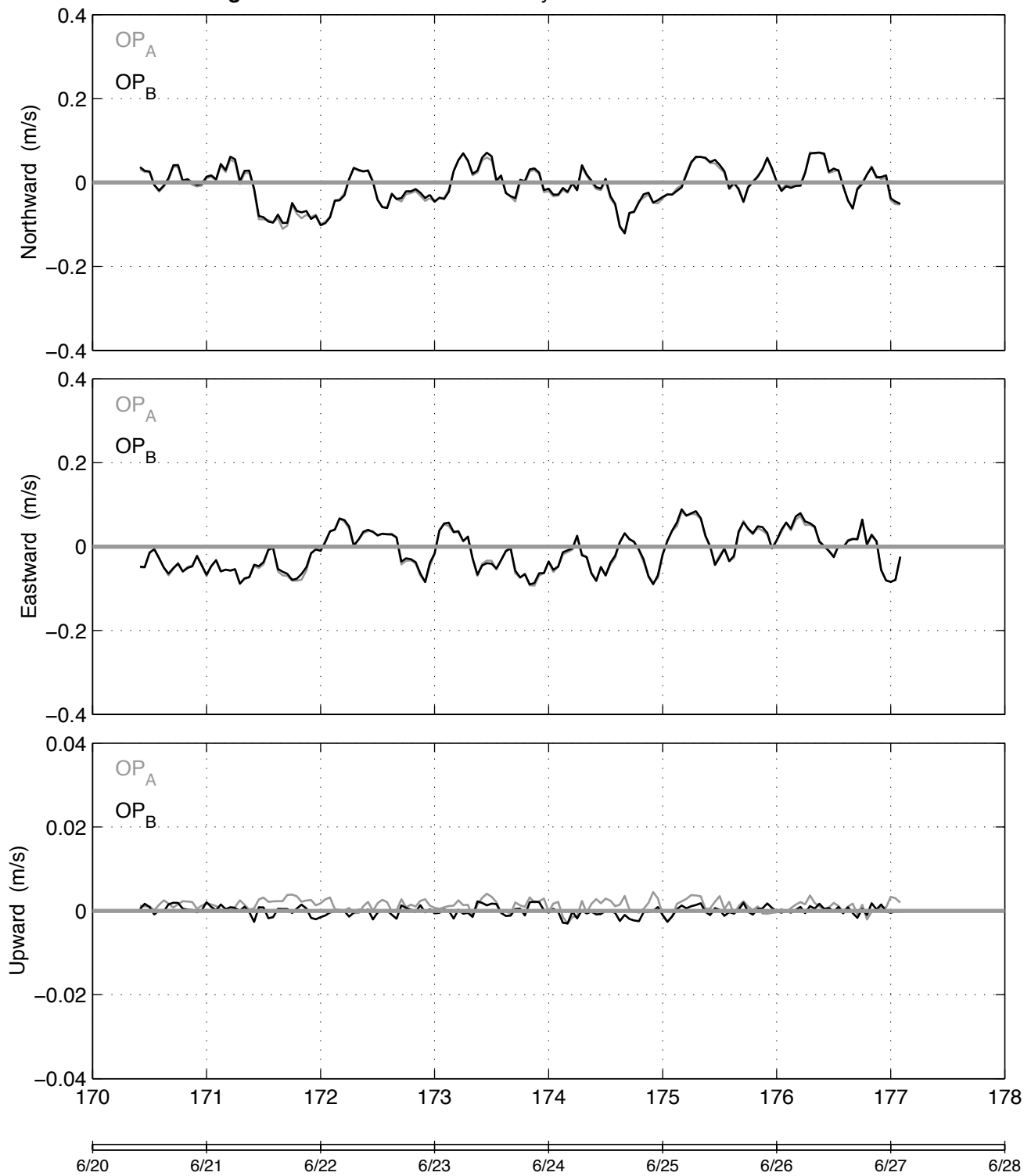
**Figure 7a. HYCODE 2000: Velocity**



**Figure 7b.** HYCODE 2000: Velocity



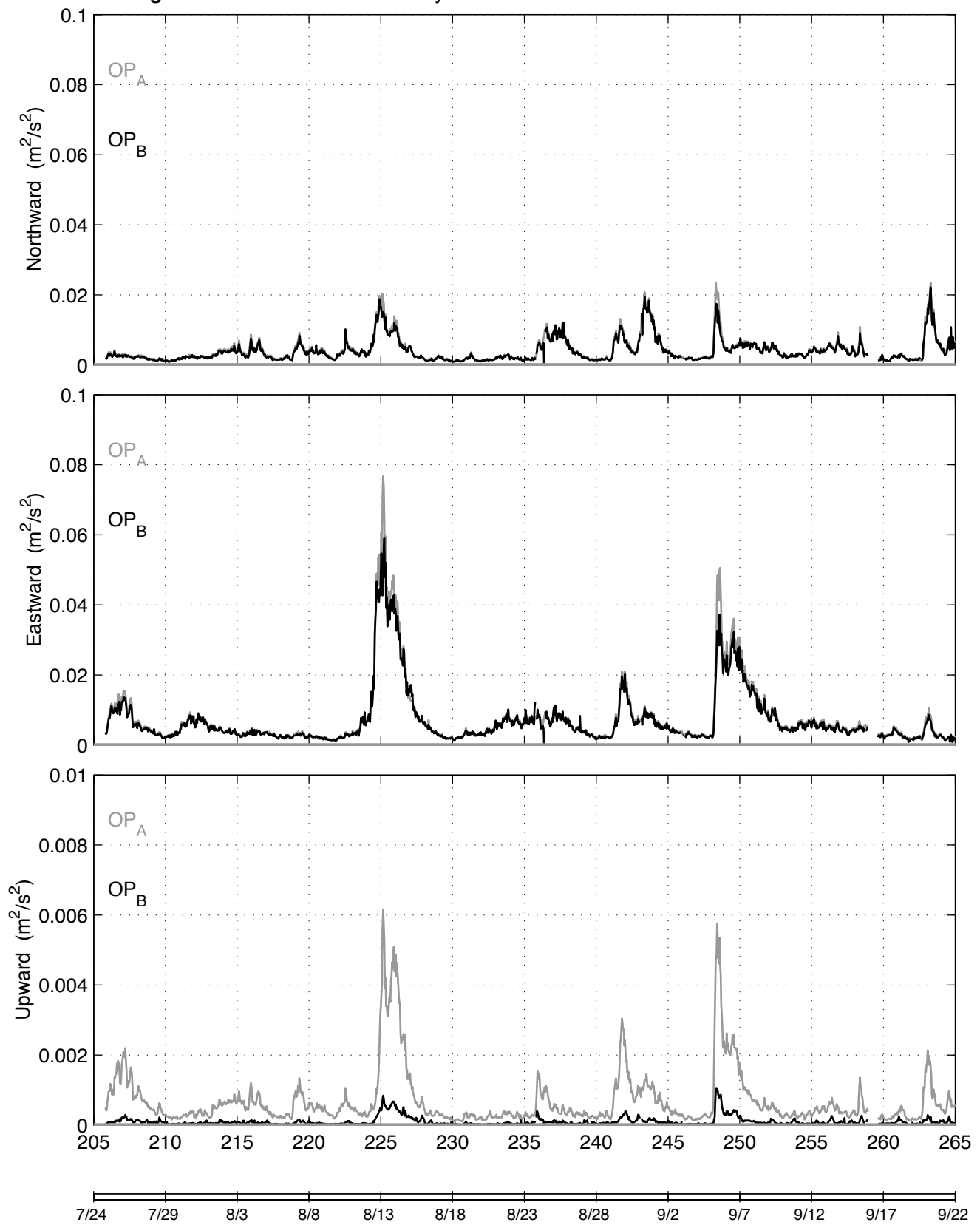
**Figure 7c.** HYCODE 2001: Velocity



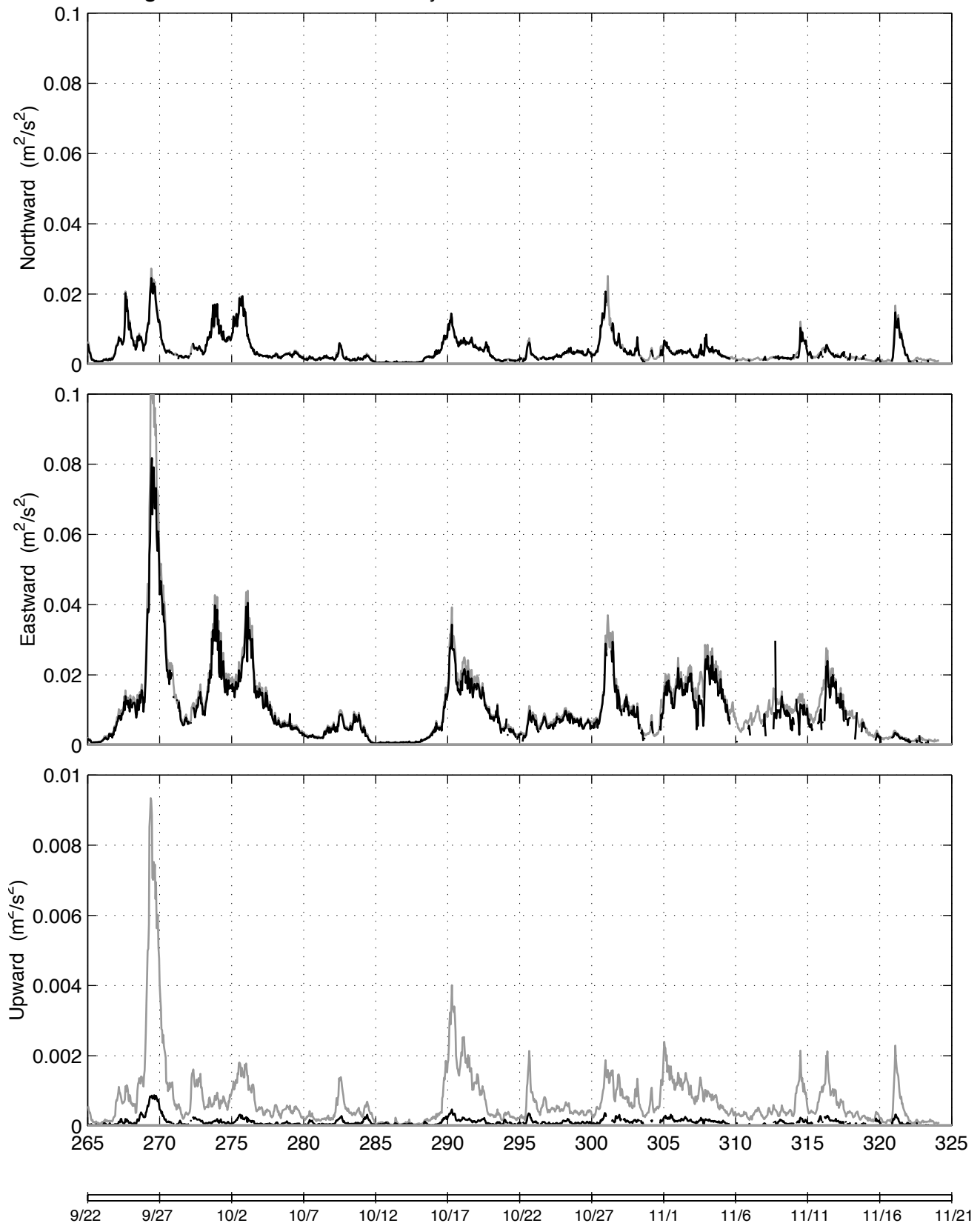


## Velocity Variances

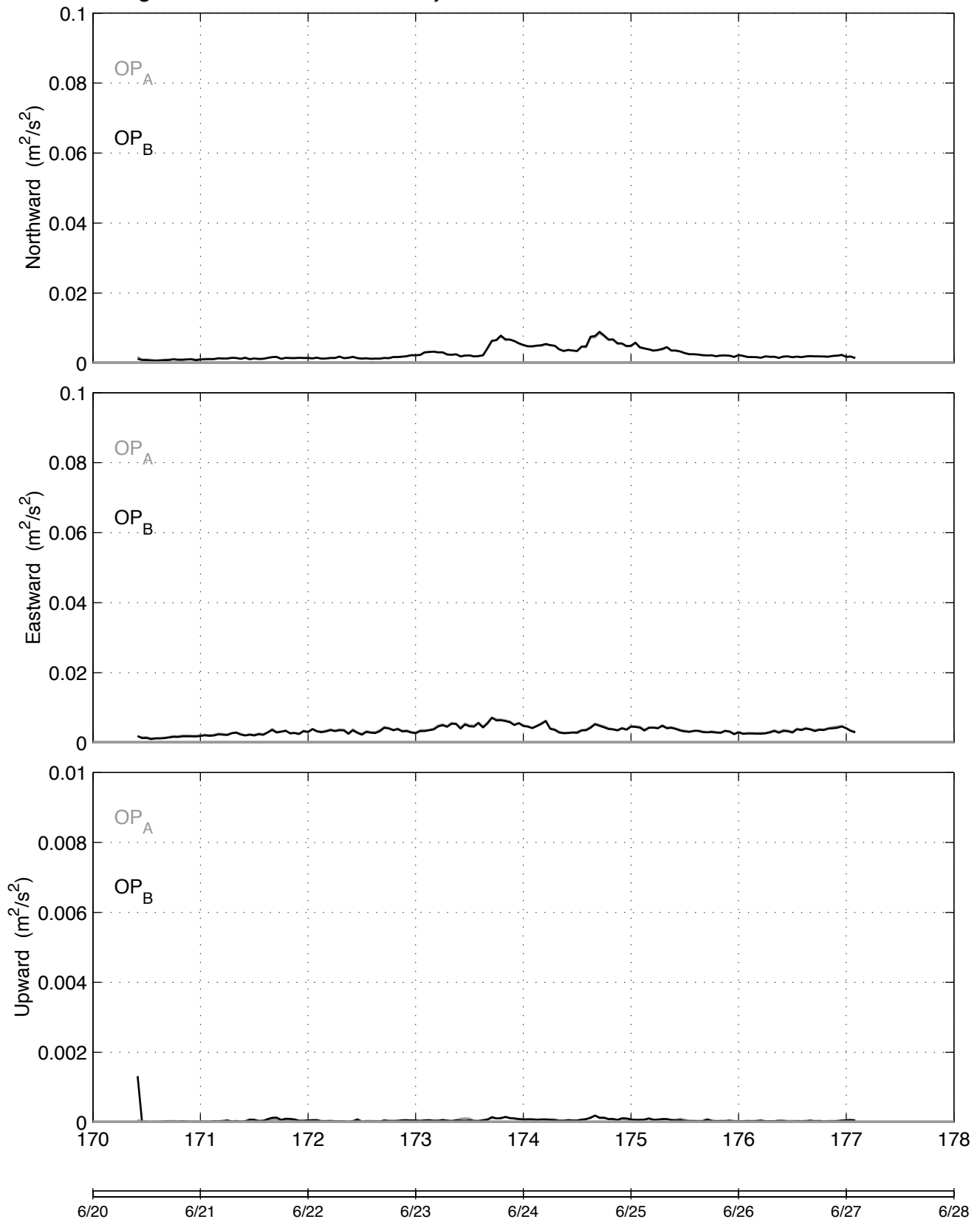
Figure 8a. HYCODE 2000: Velocity Variance



**Figure 8b. HYCODE 2000: Velocity Variance**



**Figure 8c.** HYCODE 2001: Velocity Variance



## **Bottom Orbital Velocity and Wave Period and Direction**

Figure 9a. HYCODE 2000:

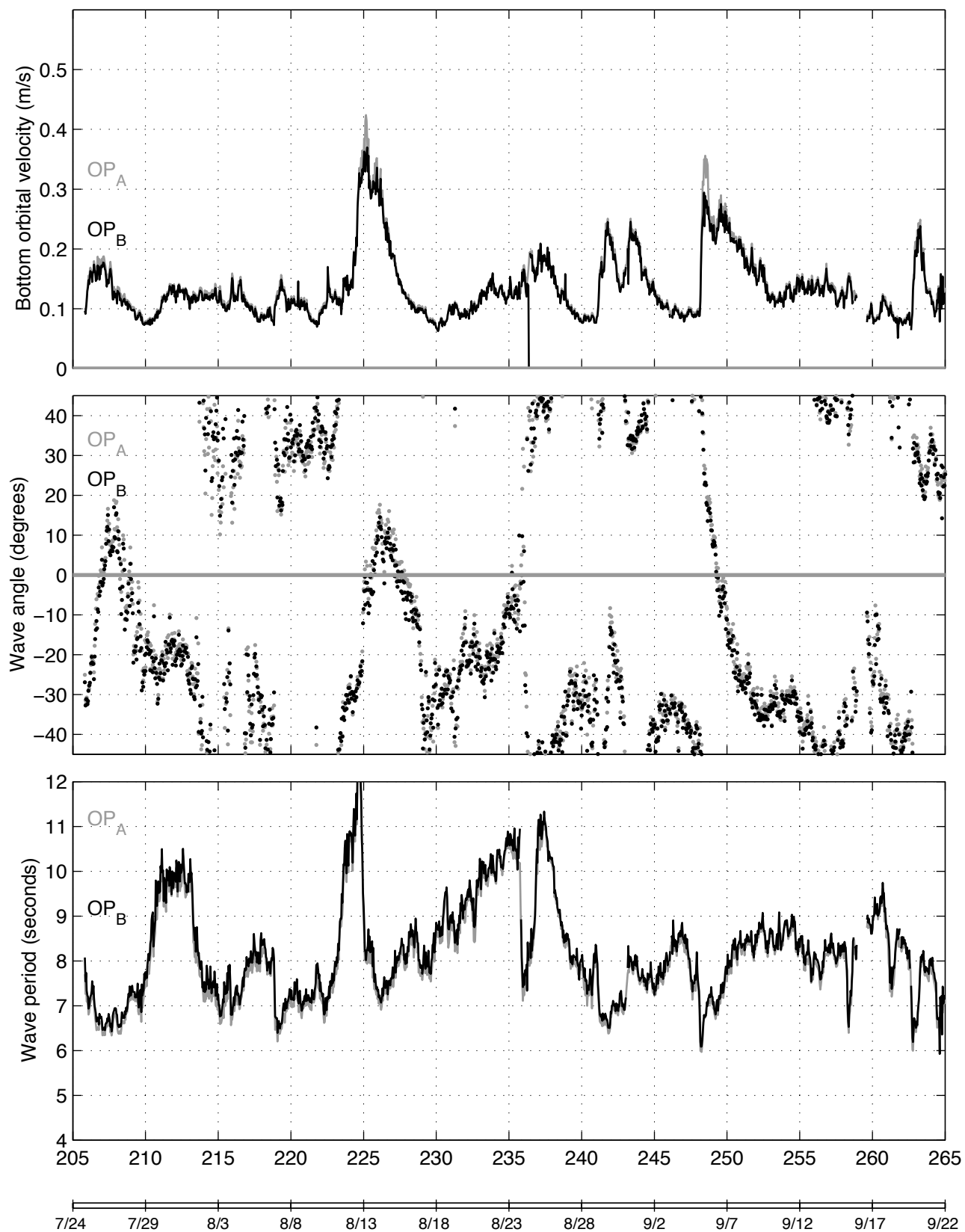


Figure 9b. HYCODE 2000:

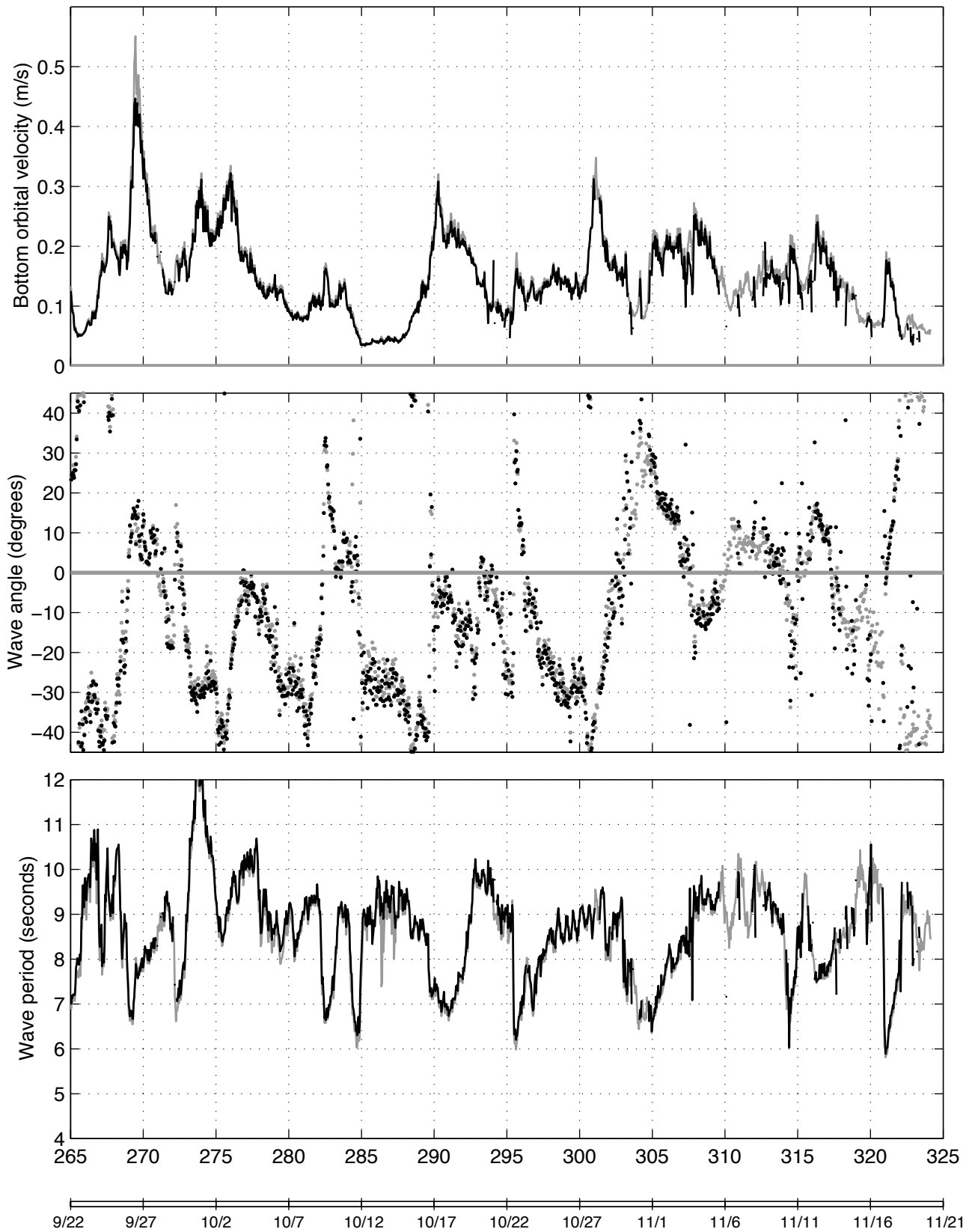
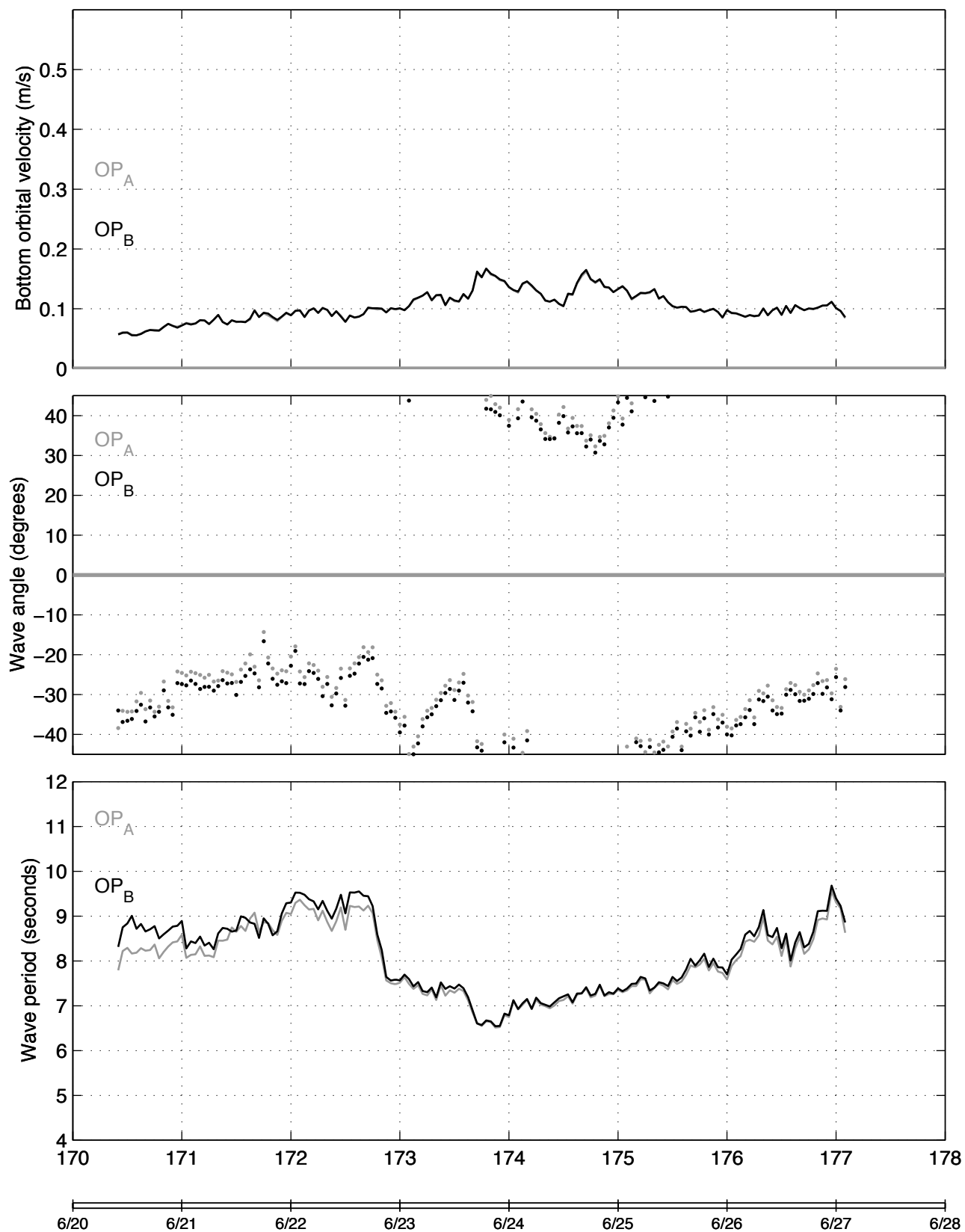


Figure 9c. HYCODE 2001:





## **Turbulent Reynolds Shear Stress & Dissipation**

Figure 10a. HYCODE 2000

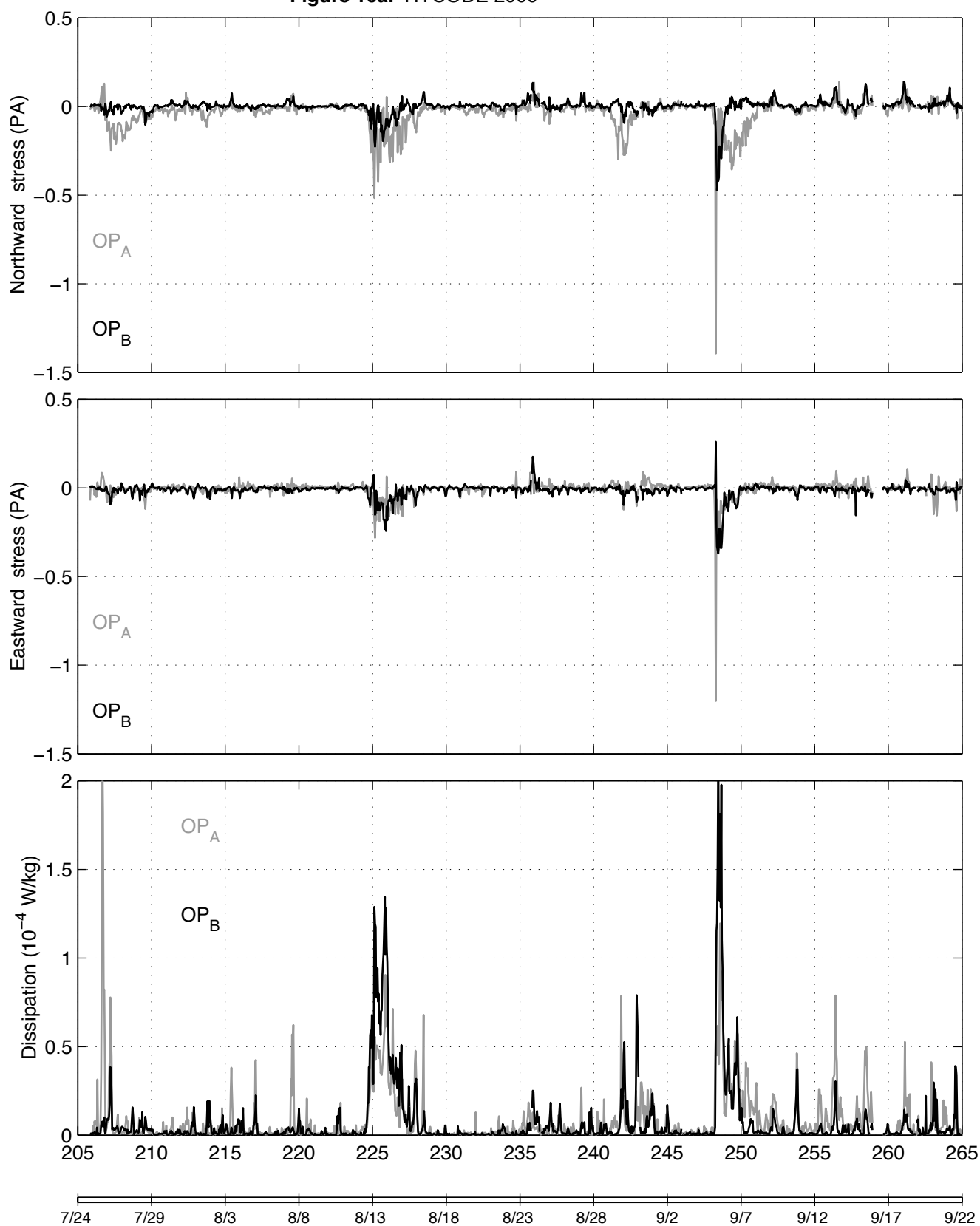


Figure 10b. HYCODE 2000

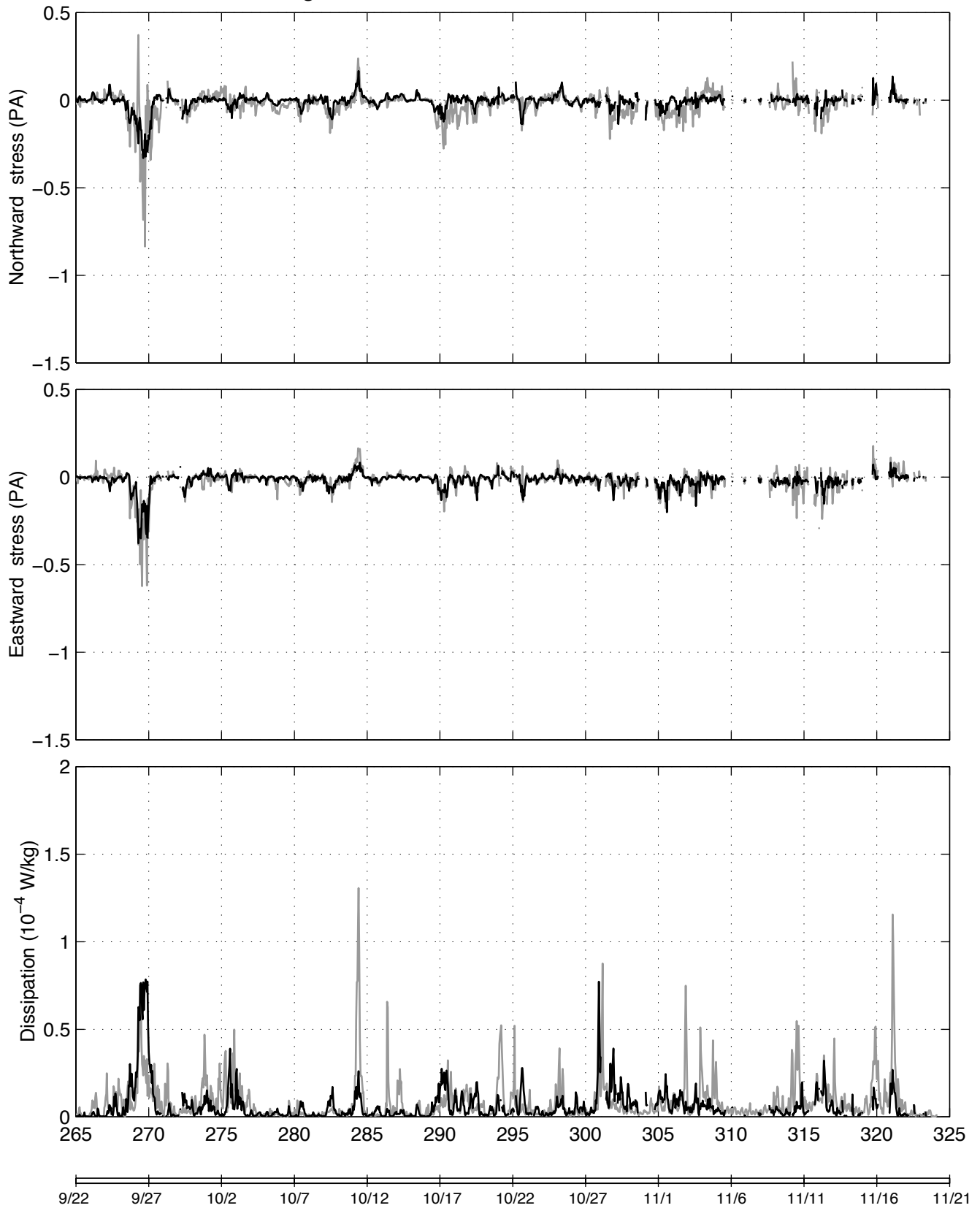
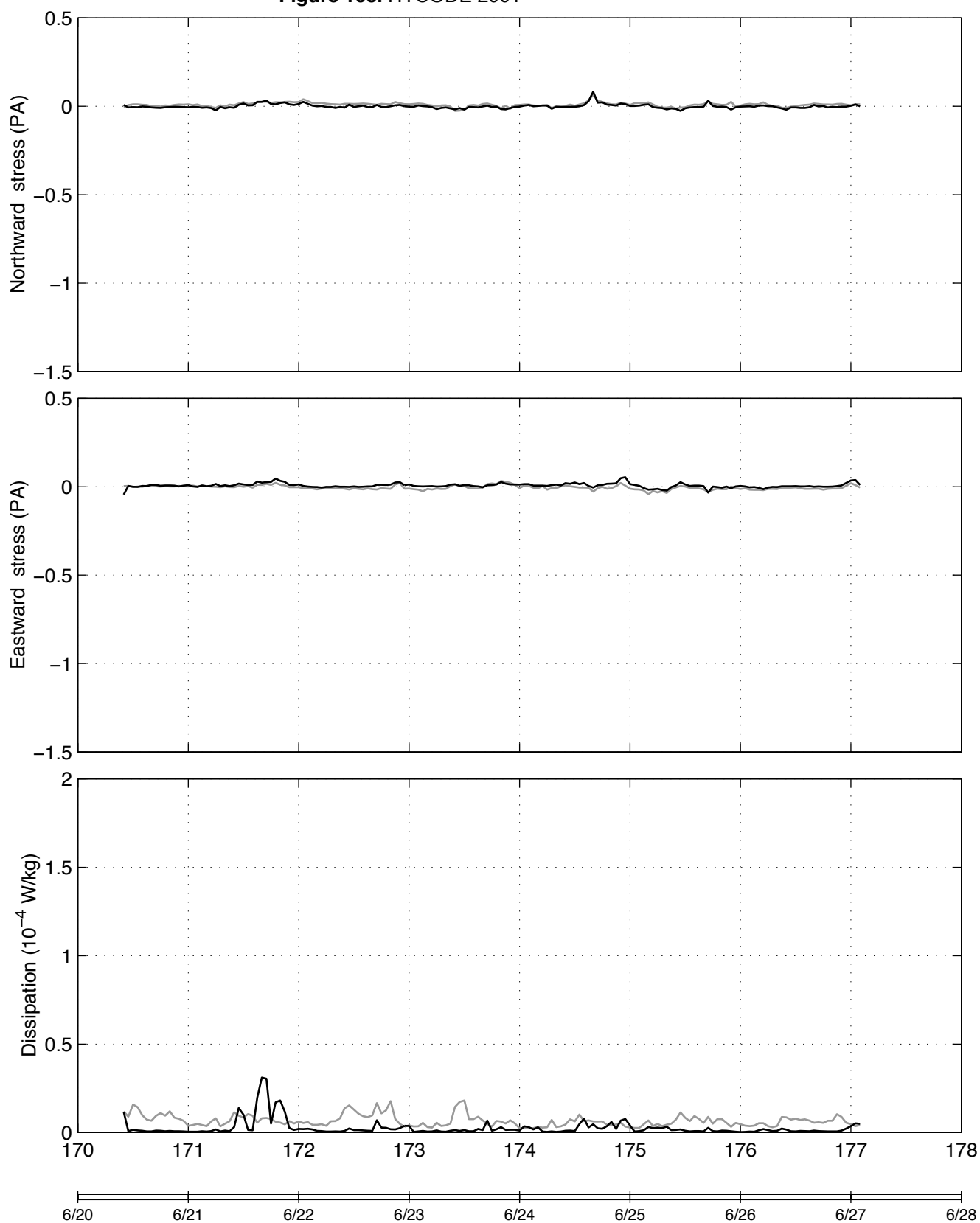
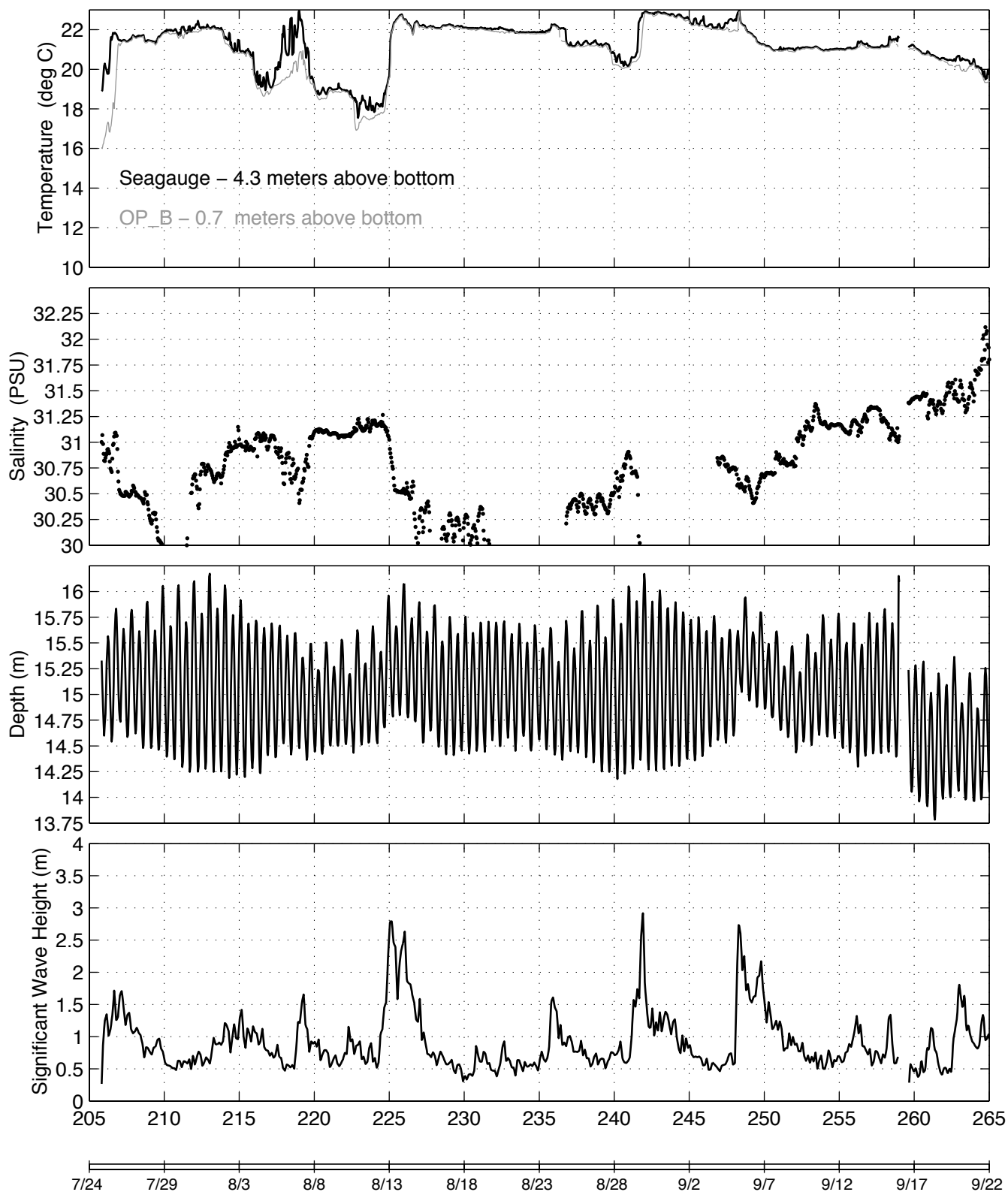


Figure 10c. HYCODE 2001

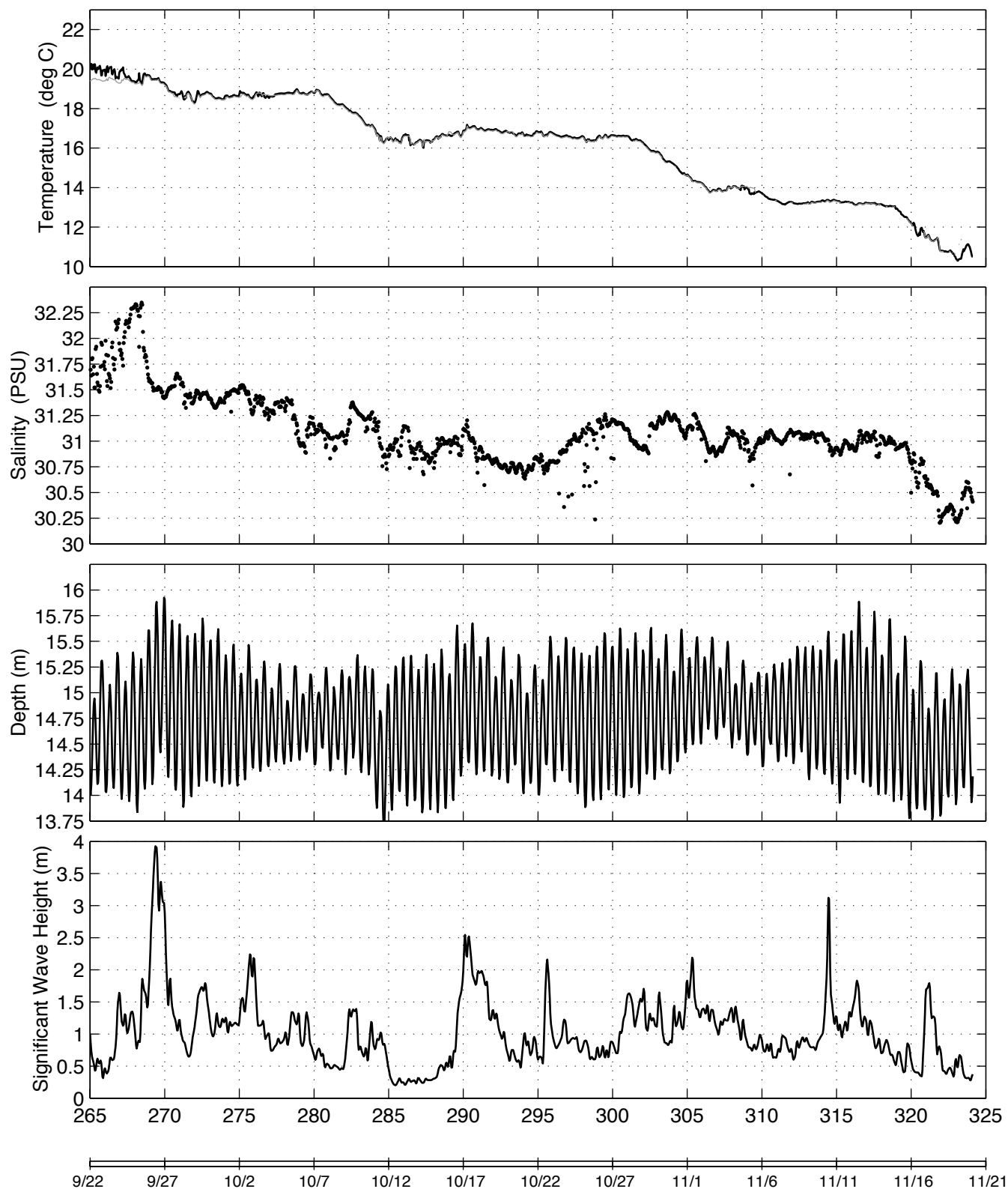


**Temperature, Salinity, Significant Wave Height & Depth  
from Seaguage at 4.3 meters above bottom**

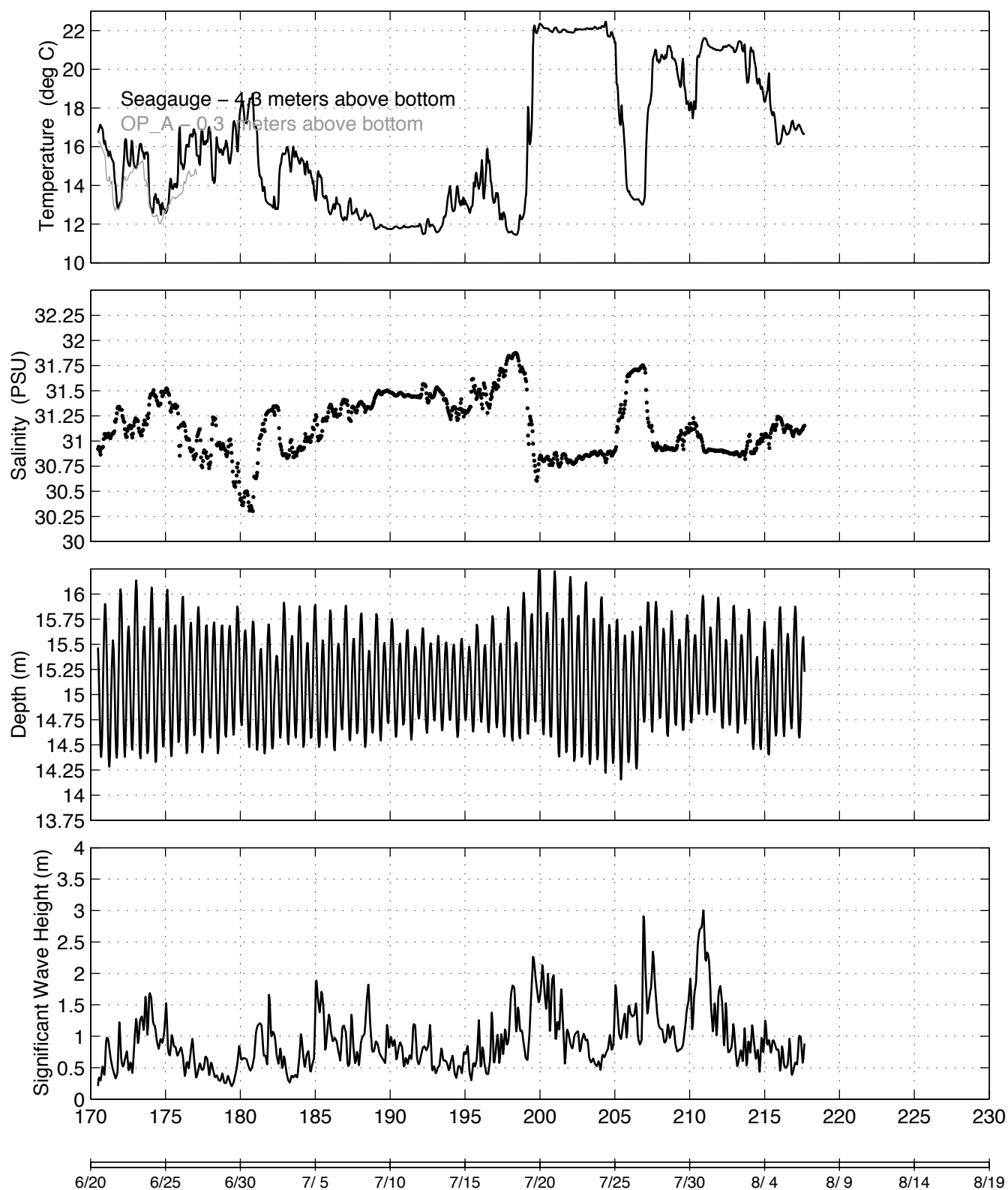
**Figure 11a. HYCODE 2000: Seagauge summary**



**Figure 11b.** HYCODE 2000: Seagauge summary



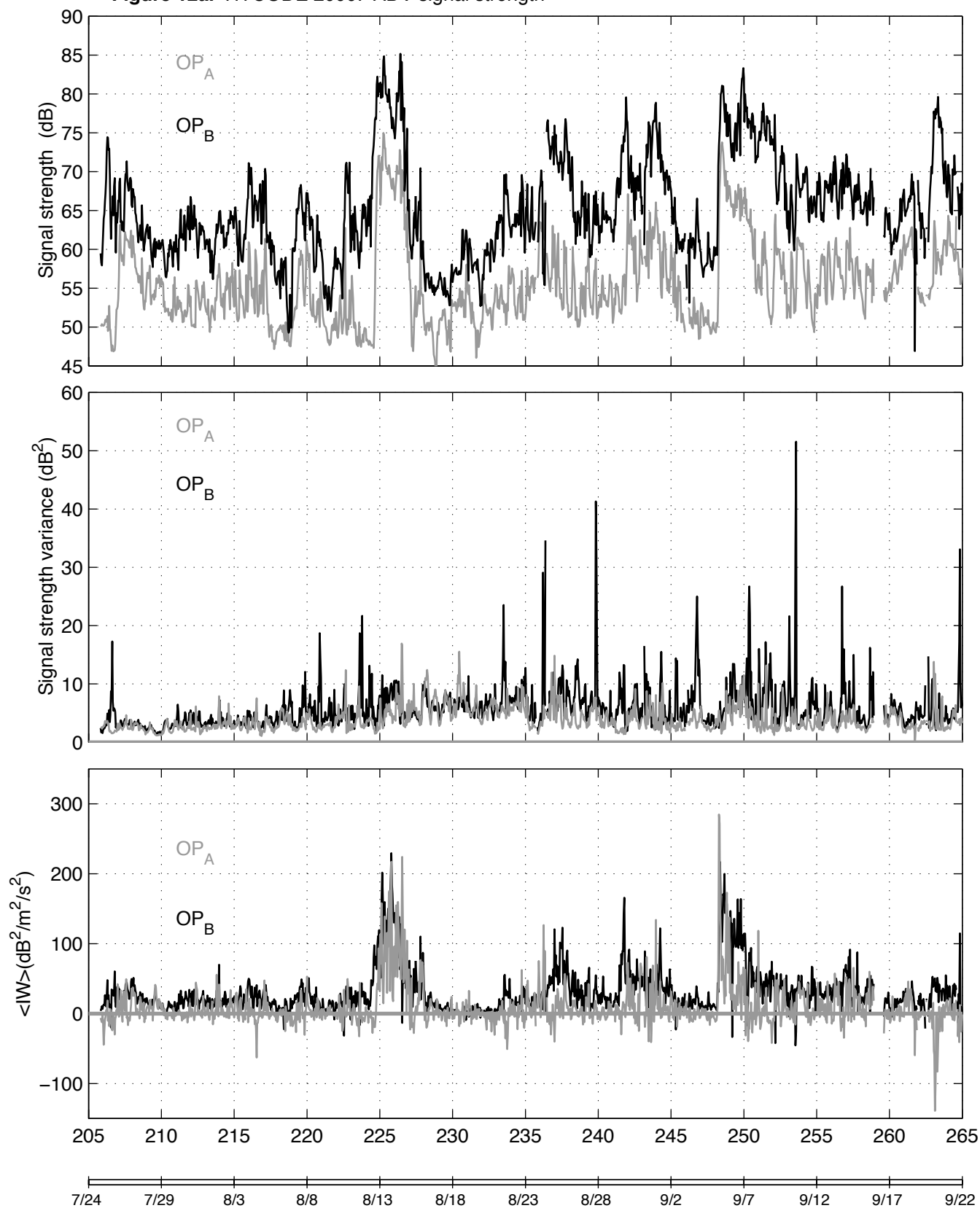
**Figure 11c.** HYCODE 2001: Seagauge summary



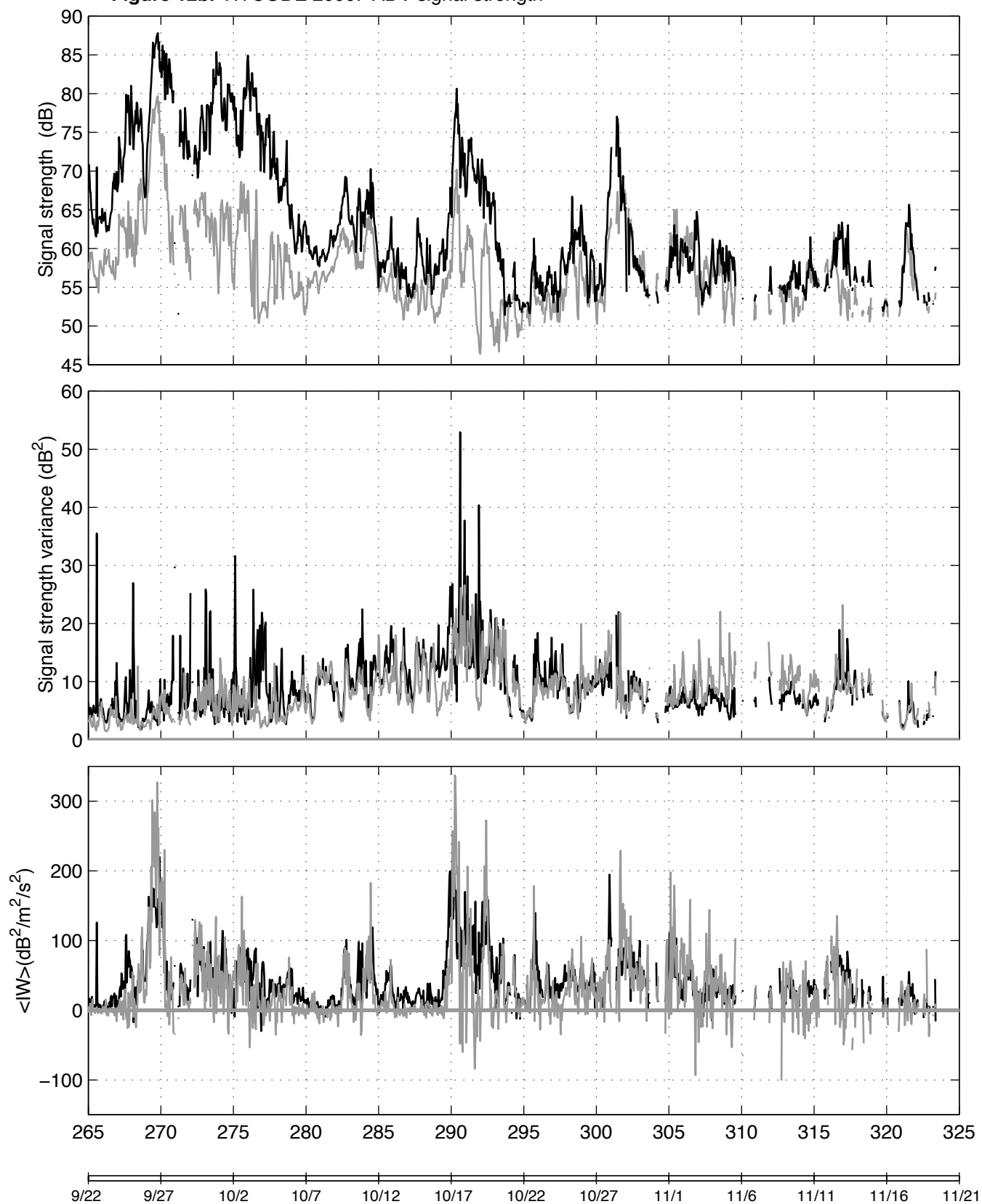


## **ADV Signal Strength & Standard Deviation (dB)**

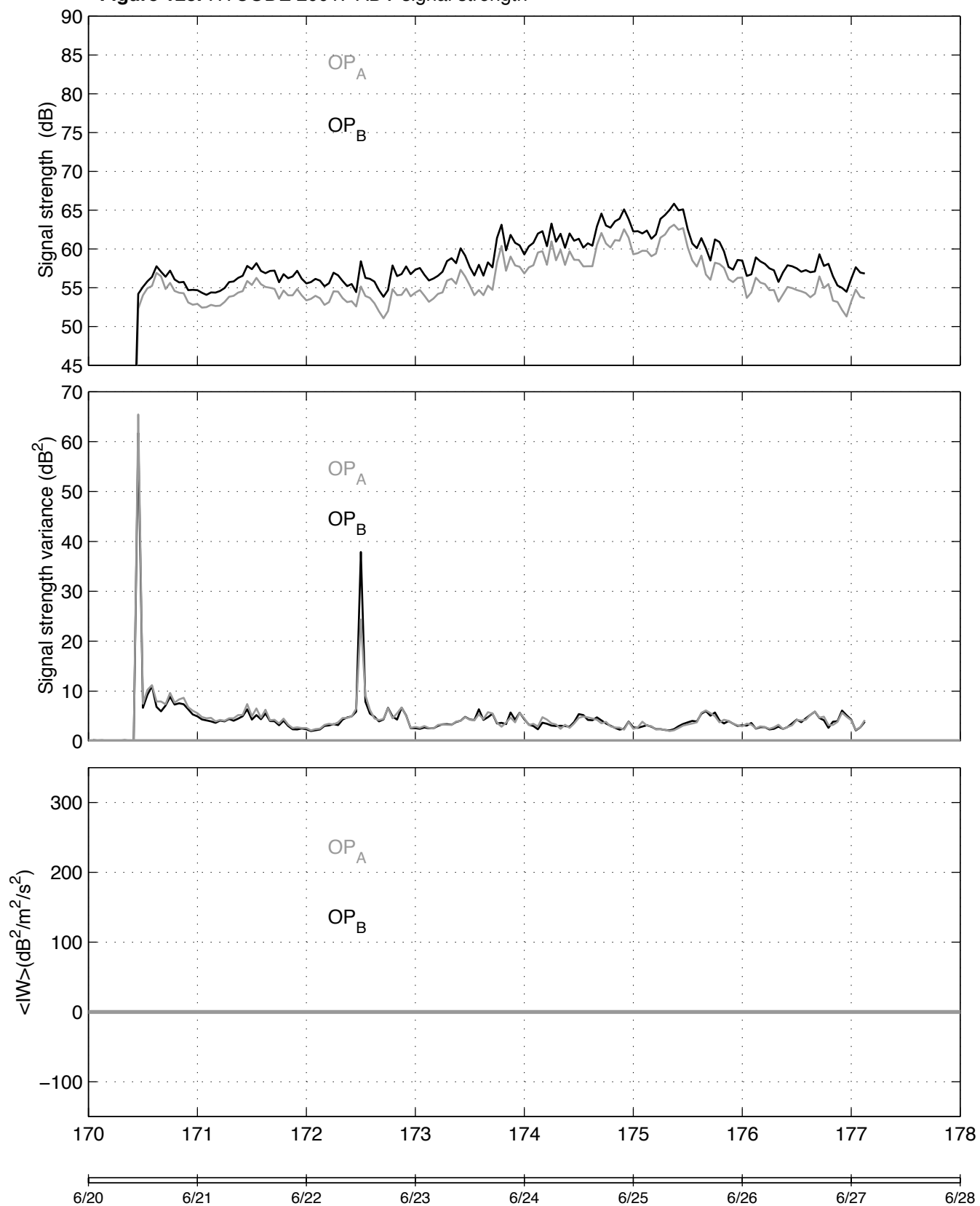
**Figure 12a.** HYCODE 2000: ADV signal strength



**Figure 12b.** HYCODE 2000: ADV signal strength

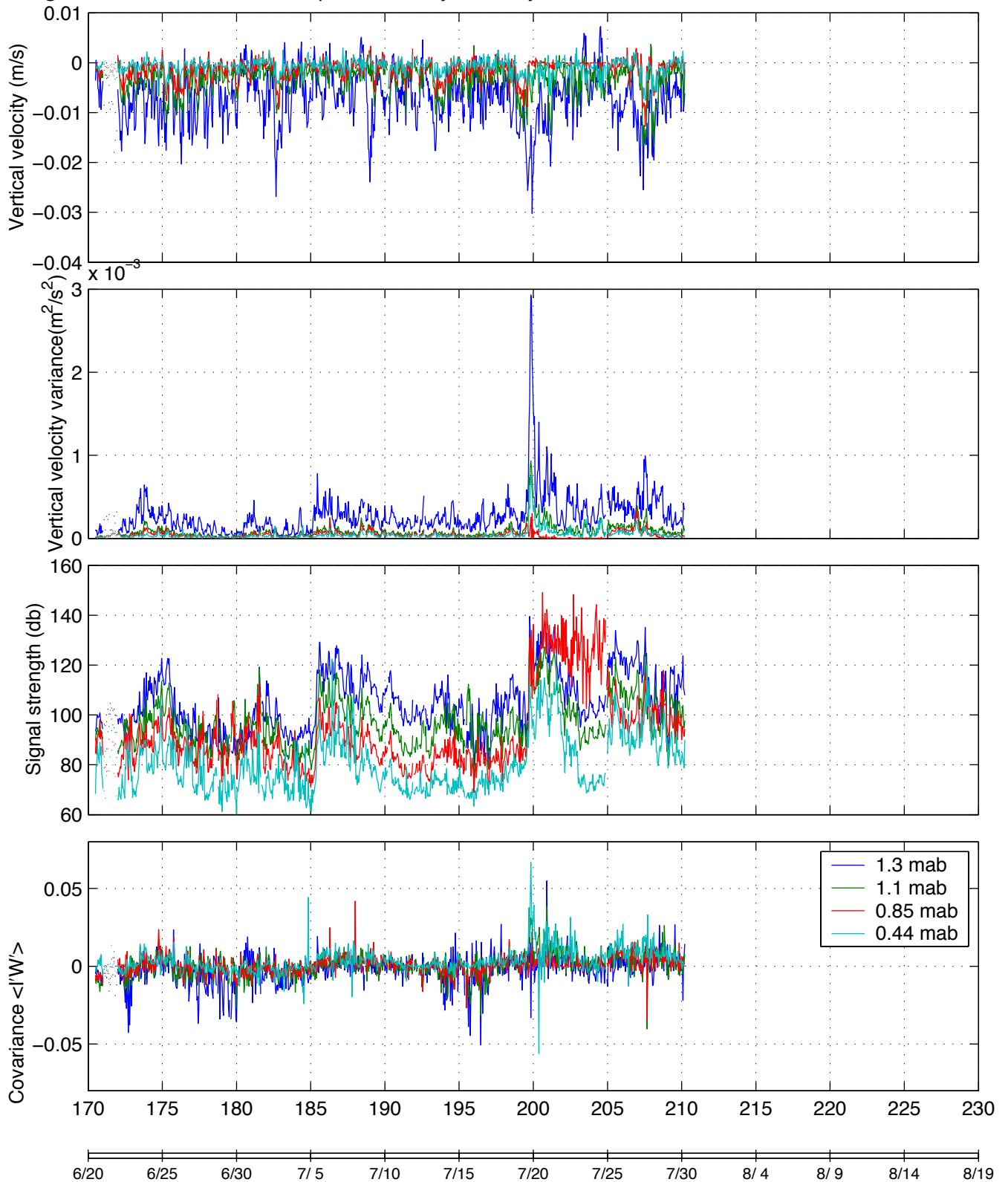


**Figure 12c. HYCODE 2001: ADV signal strength**



**Dopbeam Vertical Velocity Summaries  
(available 2001 only)**

**Figure 13.** HYCODE 2001: Dopbeam velocity summary



## VI. DATA ANALYSES

This section includes some of the preliminary analyses which were conducted in the evaluation of the Trowbridge data.

A tidal filter was used to provide tide data from pressure records (Rosenfeld, 1983). Figure 14a shows highly correlated tide data collected by the Seagauge (at 4.3 mab) and by ADV OP<sub>A</sub> (at 3.9 mab) pressure sensors. Figure 14b shows a drift in the observed depth of the ADV OP<sub>A</sub> strain-gauge pressure sensor.

Figure 14a.

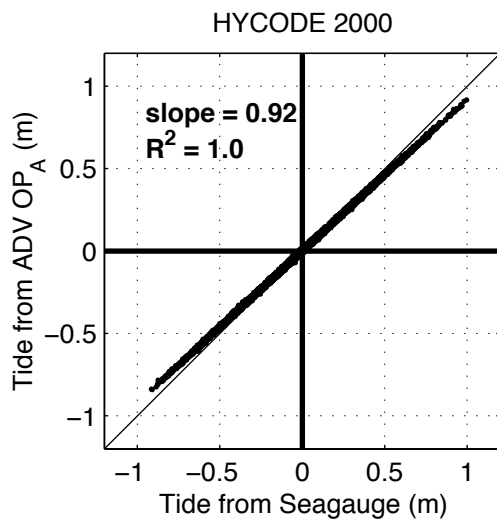


Figure 14b.

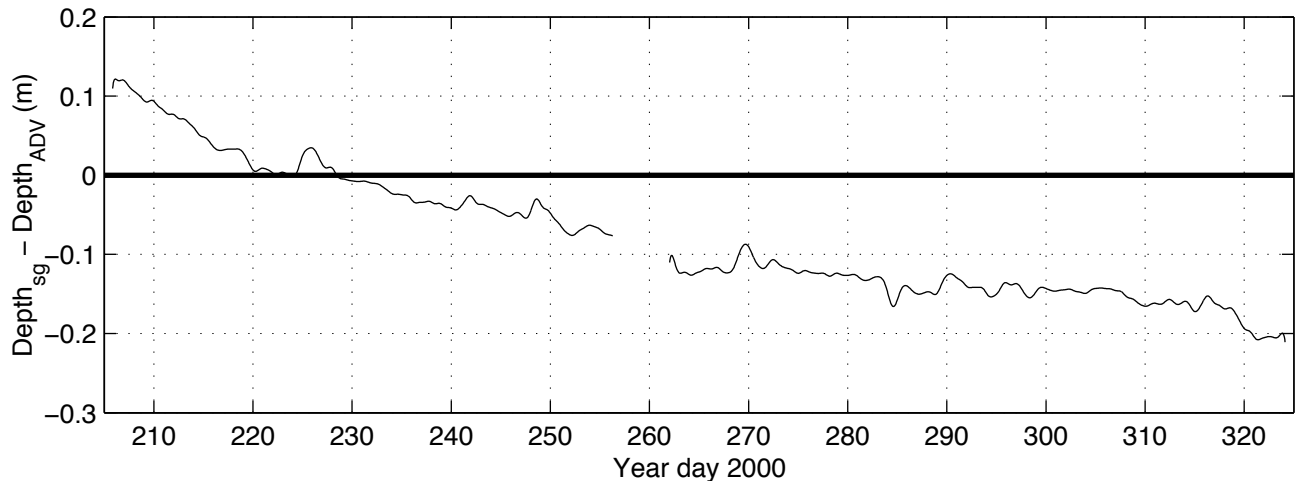
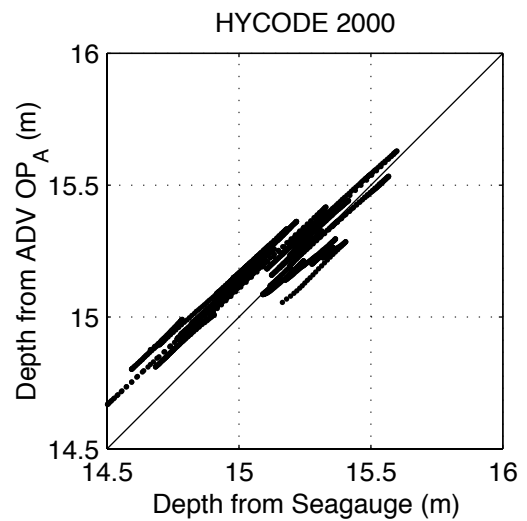


Figure 14c. Comparison of pressure data from the Seagauge Paroscientific and the ADV strain-gauge.

The significant wave height computed from the ADV OP<sub>A</sub> pressure is compared with H<sub>s</sub> computed from the ADV OP<sub>A</sub> velocity and that reported from the Seagauge. The ADV velocity and pressure spectral densities were converted to surface spectra (S<sub>ηη</sub>) using linear wave theory (Dean, et.al, 1984) and integrated under the wave peak as follows:

S<sub>ηη</sub> from velocity (0.05 < f < 0.5 Hz)

S<sub>ηη</sub> from pressure integrated from 0.05 < f < 0.21 Hz.

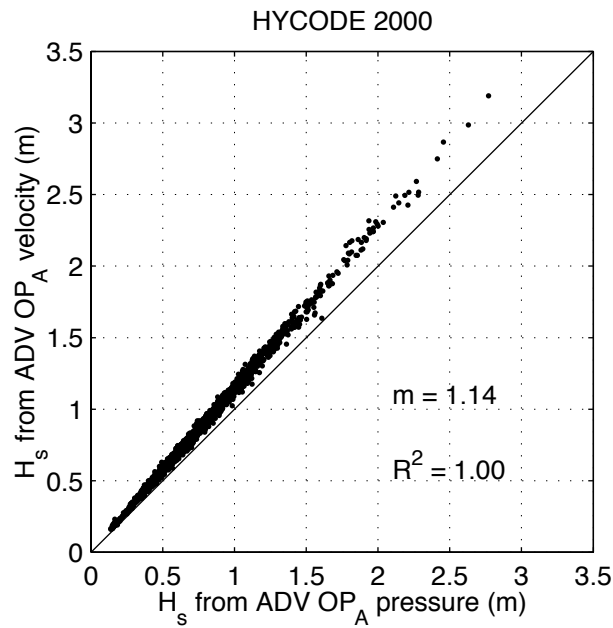


Figure 15 a.

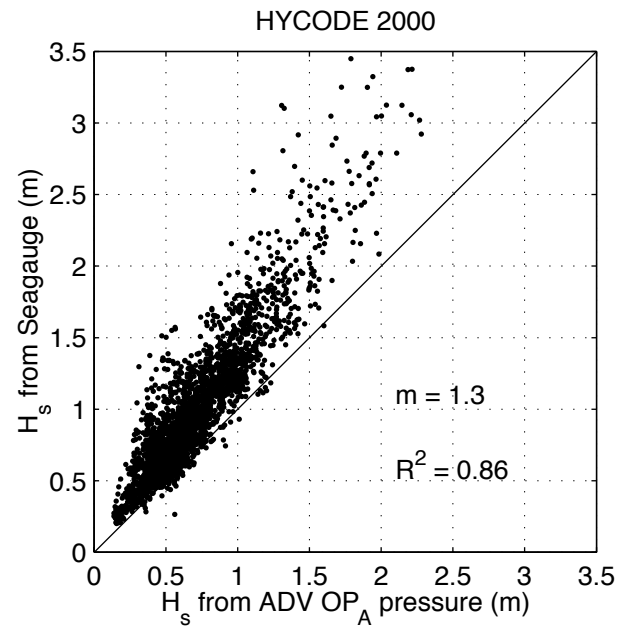


Figure 15 b.



The Seagauge temperature and salinity are presented below with those observed from the shipboard CTD casts.

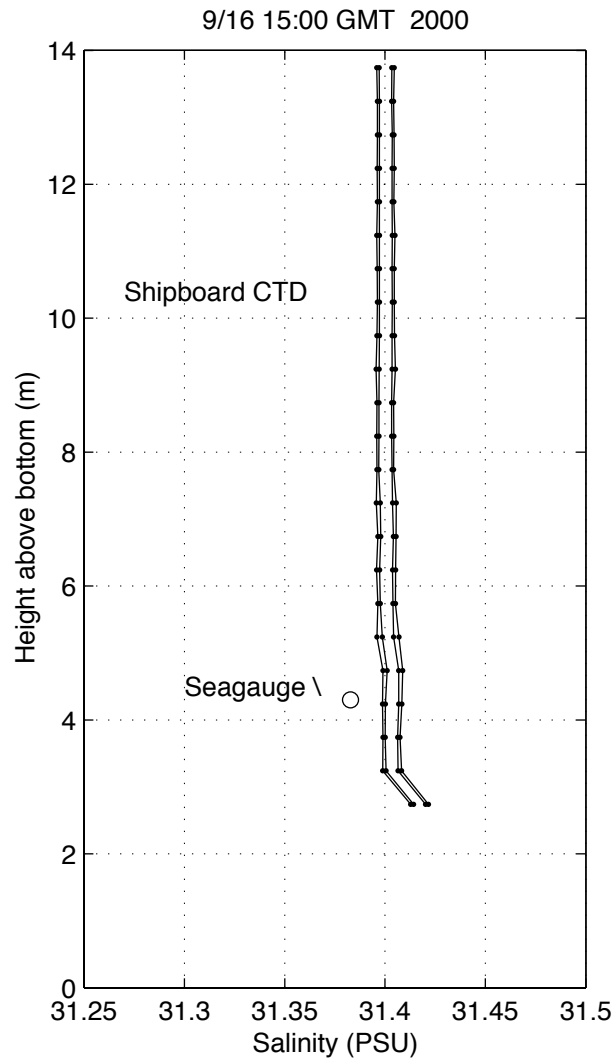


Figure 16 a.

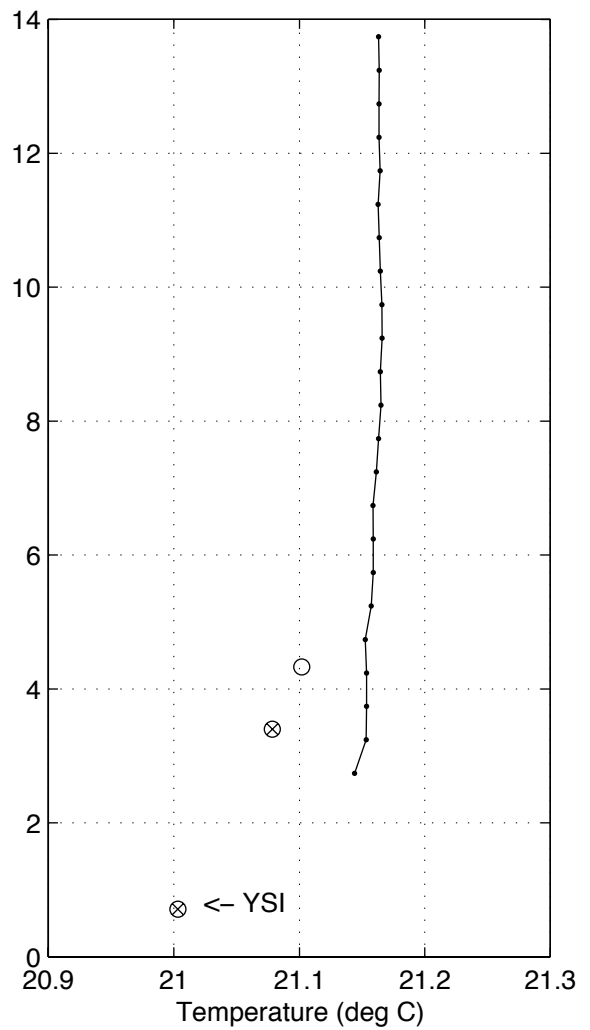
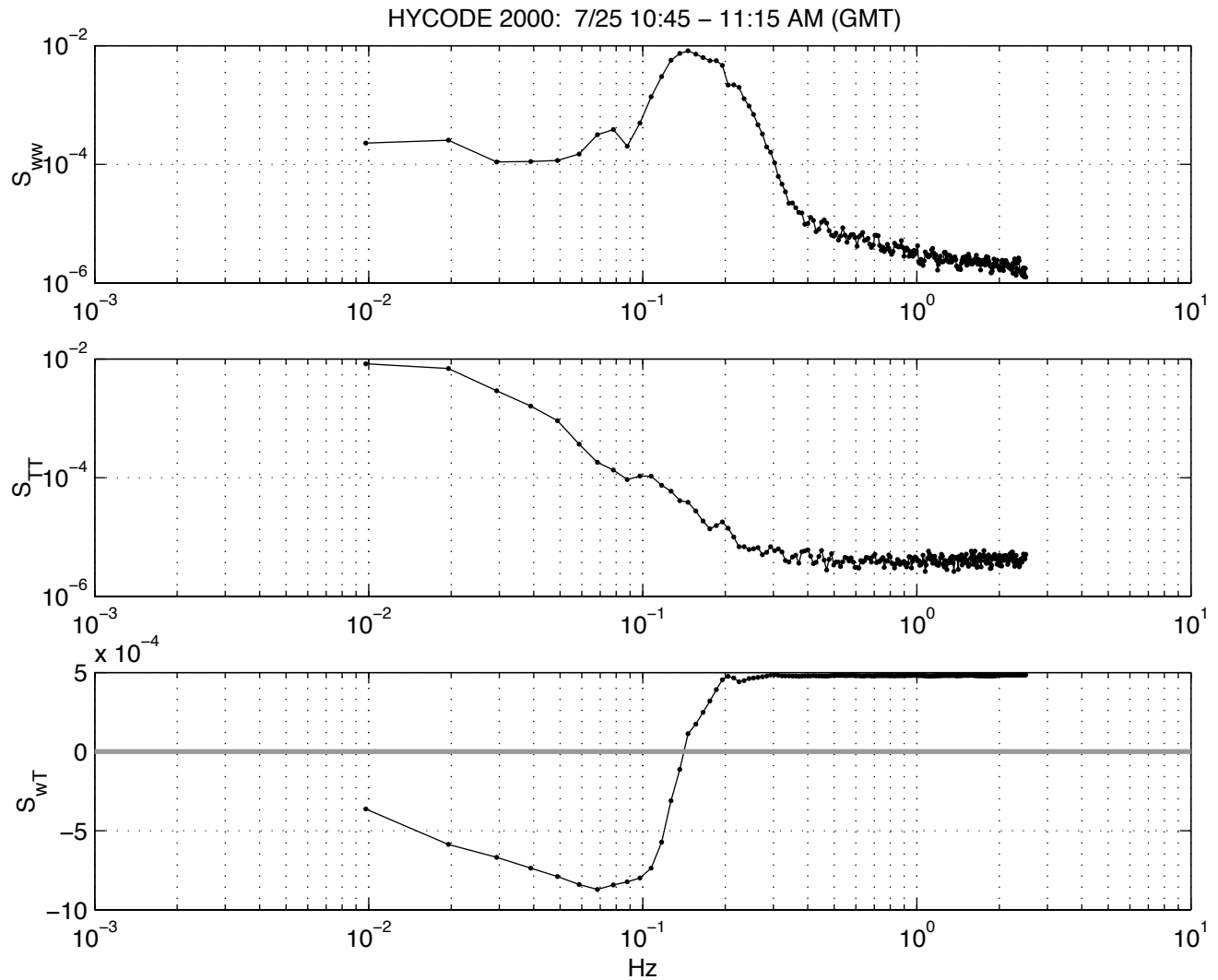
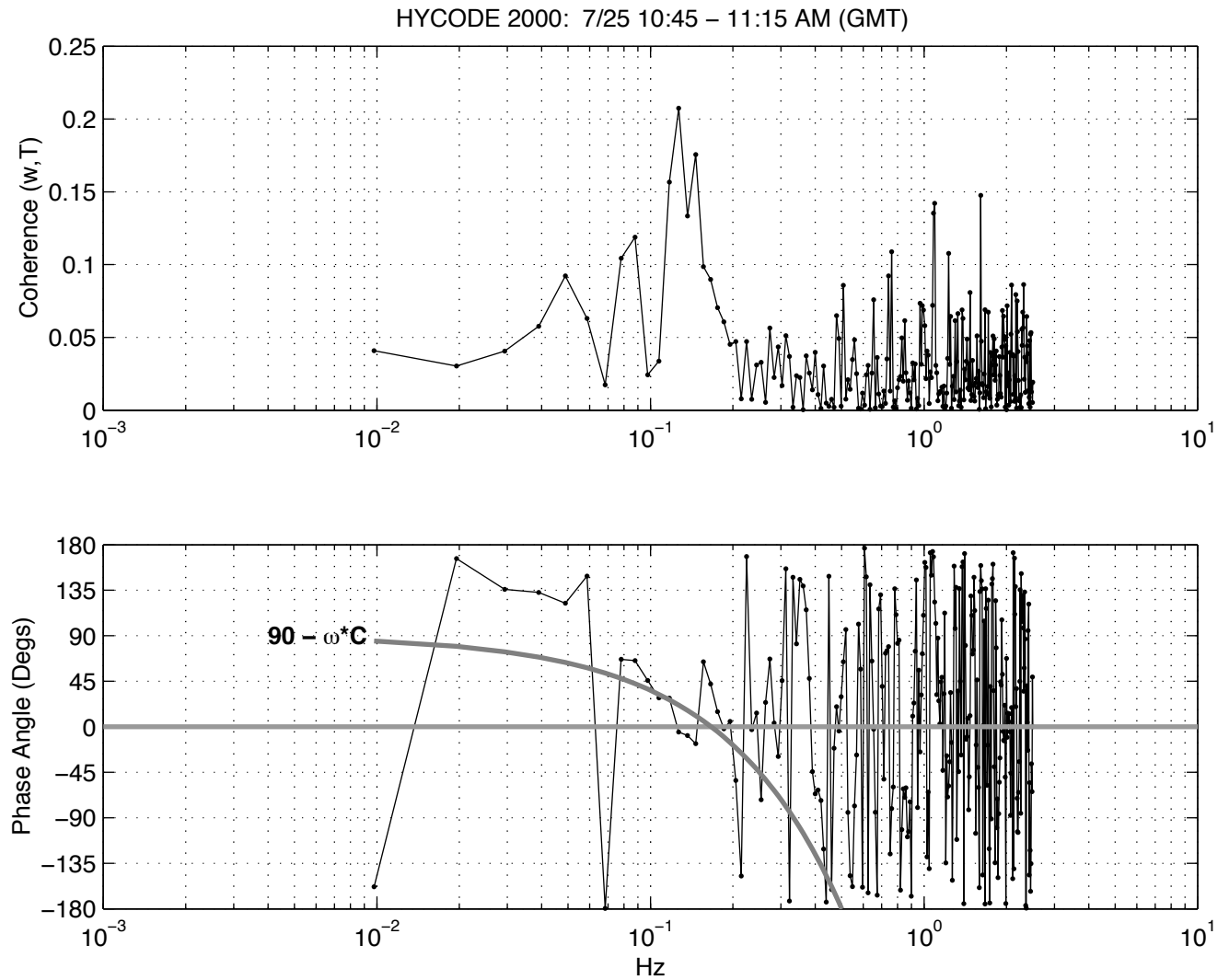


Figure 16 b.

Figures 17 and 18 show spectral analyses of vertical velocity ( $w$ ) from ADV OP<sub>A</sub> (m/s) and temperature ( $T$ ) from a nearly co-sampled YSI (Deg C) during a period of stratification ( $dT/dz = 1.61$  DegC/m). The horizontal flow was 0.27 m/s southward and the velocity gradient ( $du/dz$ ) was  $0.10 \text{ s}^{-1}$ .

**Figure 17.** Spectral densities of vertical velocity and nearby temperature during a period of stratified flow.

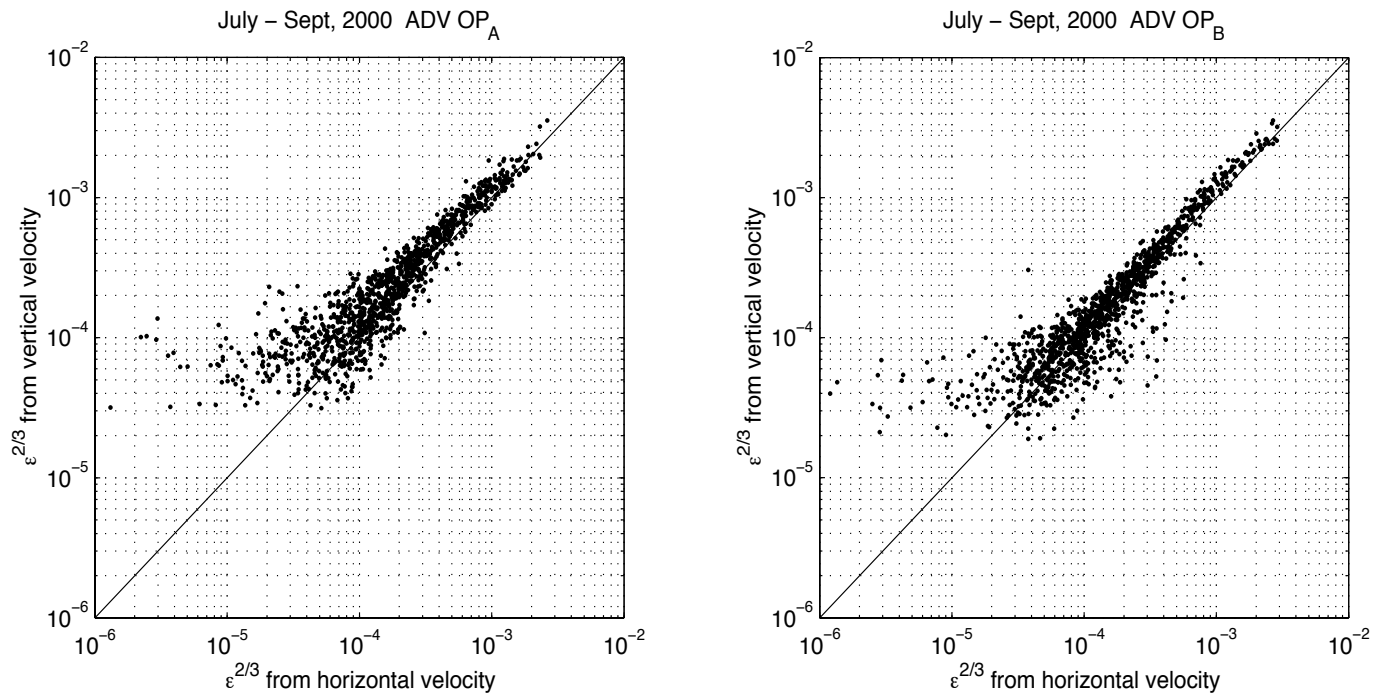


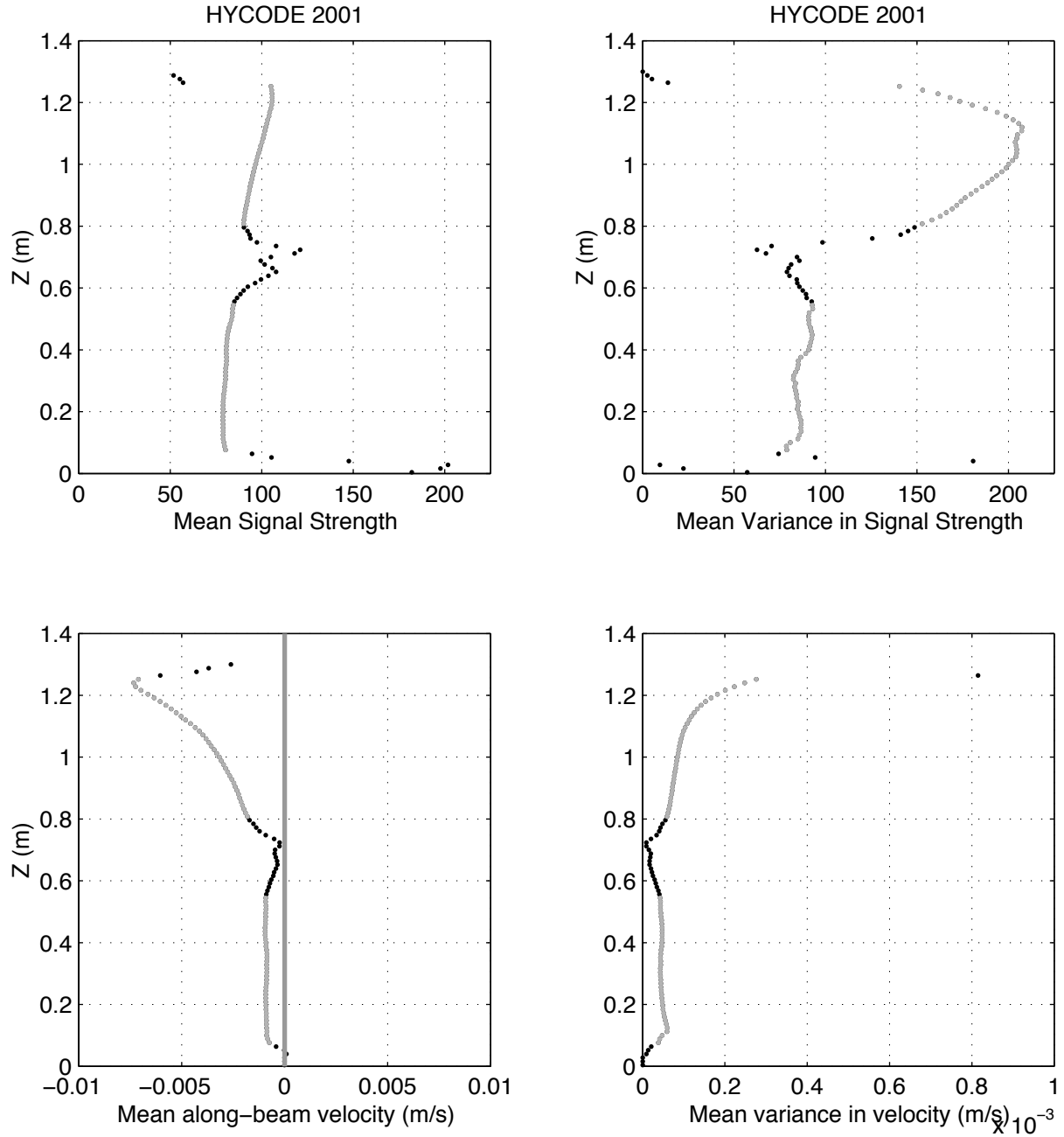


**Figure 18.** For the model  $(90 - \omega C)$ , where  $\omega = 2\pi f$  and  $C$  represents a best fit time response constant of 1.5 seconds. The phase result indicates that the temperature measurements were influenced by a non-zero time-response constant in the temperature sensor.

Figure 19 provides a comparison of the dissipation computed from horizontal velocity with that derived from vertical velocity of each ADV sensor. The ADV sensors have a higher noise floor in the XY plane, which was subtracted out to obtain the estimates of dissipation from the horizontal velocity. Since each probe was at a different height during 2000, dissipation estimates of each sensor are not compared against each other. During 2001, ADV OP<sub>A</sub> was set at a high resolution and therefore had a noise floor which precludes good estimates of dissipation from that sensor.

**Figure 19.**





**Figure 20.** Dopbeam summaries from June - July, 2001. Black represents all heights, grey represents the bins flagged by the variable  $nz$  in the data summary files in Section VII.

Outside the regions of increased intensity, most likely a result of multipath reflection, the dop-beam appears to provide good estimates of vertical velocity.

The relationship of cos/sine of the DopBeam is typically defined by a circle. For reasons not understood, the collected data are defined more angularly, as shown in Figure 21.

**Figure 21.** Shows the shape of the cos/sine subsampled data at  $z = 0.54$  mab.

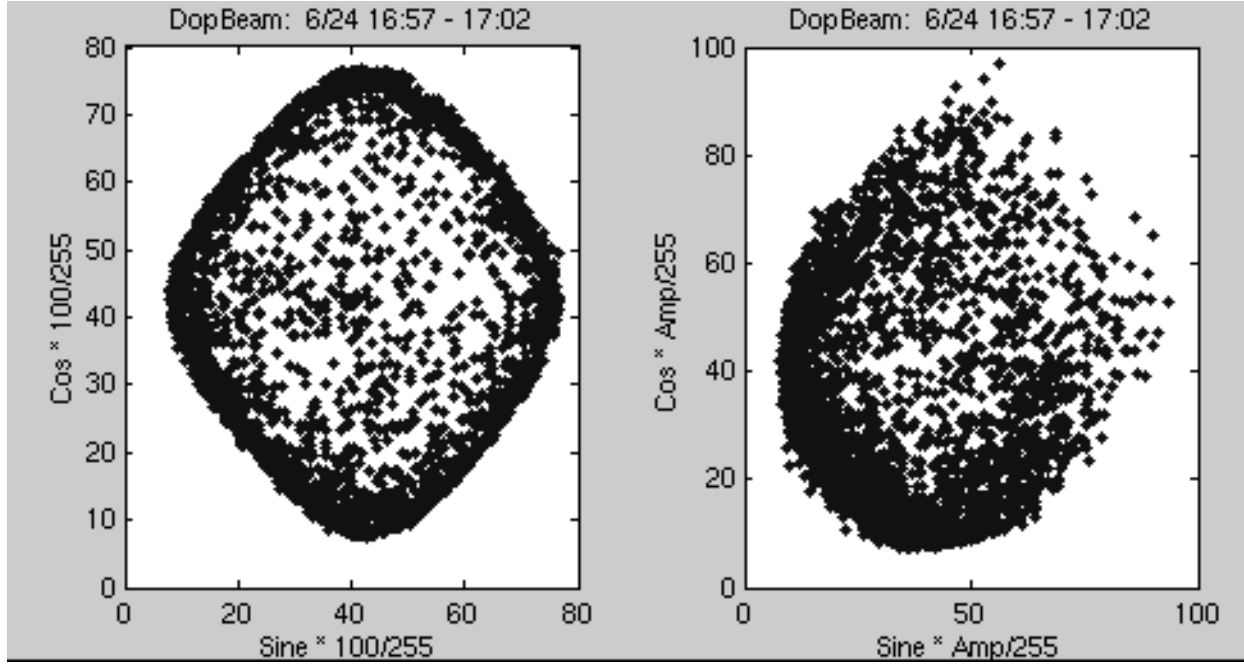
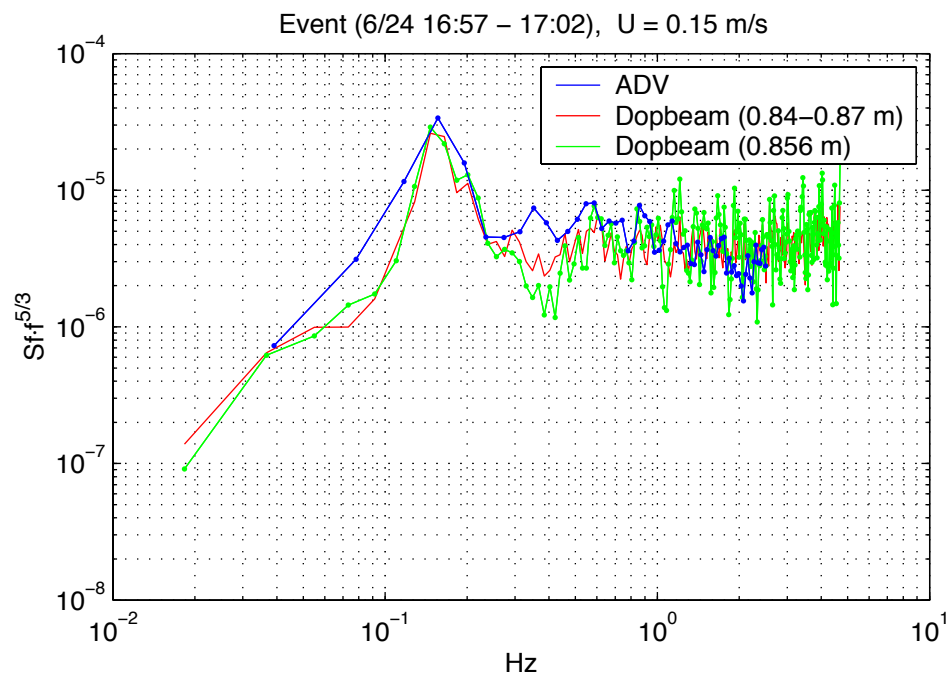
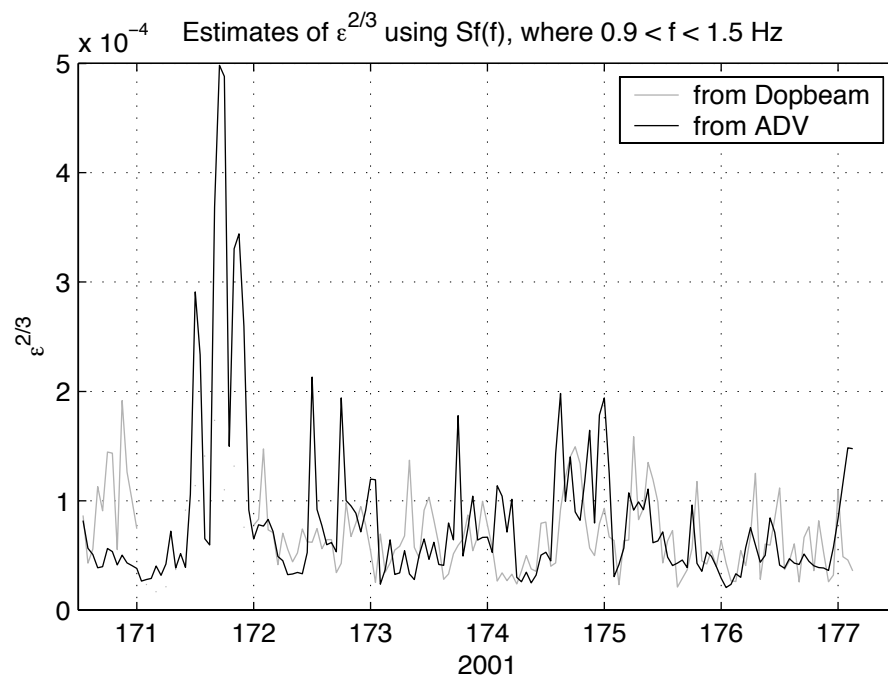


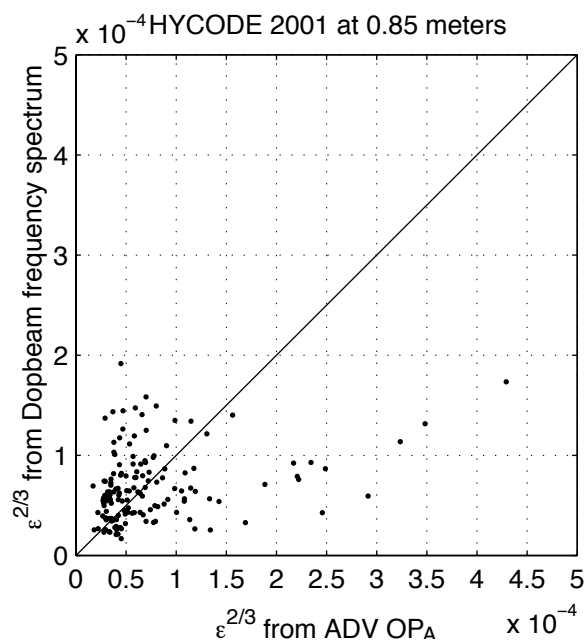
Figure 22 shows a comparison of spectral estimates of vertical velocity variance for a five minute period when the velocity was about 12 cm/s. Figures 23 and 24a confirm a qualitative agreement in the estimates of  $\epsilon^{2/3}$  from the ADV and the Dopbeam (using simultaneous horizontal velocity from the ADV). Since the Dopbeam provides a direct wave number spectra, an estimate of  $\epsilon^{2/3}$  was computed by regressing the wave number spectra ( $S_k$ ), computed over 3 bins, with  $9/55 \cdot \alpha \cdot k^{-5/3}$ , where  $\alpha = 1.5$ , which is the empirical Kolmogorov constant. A comparison dissipation computed from time with that computed from space is found in Figure 24b.



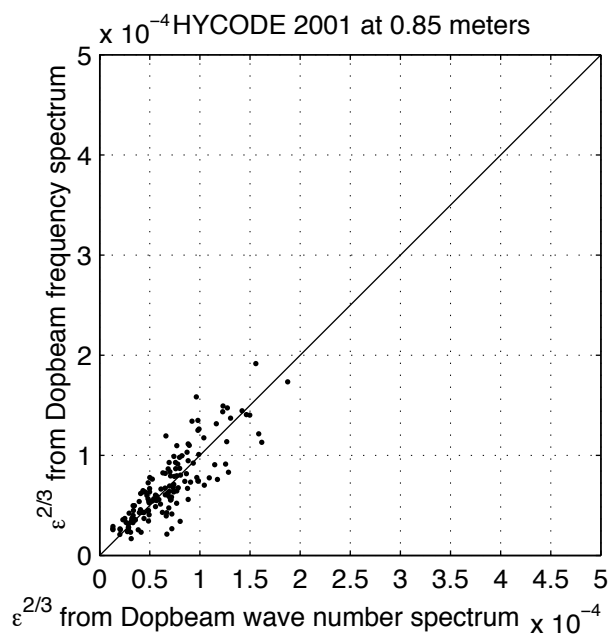
**Figure 22.**



**Figure 23.**



**Figure 24a.**



**Figure 24b.**



## VII. FILE DESCRIPTIONS

### Raw Data Descriptions

The ADVs were simultaneously logged at 5Hz with five of the YSI sensors. These data were logged as follows:

ADV ocean probes format					
Each block began with a date stamp (GMT): MMDDHHMMNSE (month,day,hour,minute,second) and was followed by 11038 records as follows:					
Variable	# variables	bytes/variable	bytes	Probe	units
Keyword(871c)	1	2	2	A	
Sample Id	1	2	2	A	1 - number of samples in burst
Velocity	3	2	6	A	(0.1 mm/sec)
Signal Strength	3	1	3	A	(counts, where 0.43 dB/count)
Correlation Coefficient	3	1	3	A	(0 to 100, where > 70 is considered ok)
heading	1	2	2	A	(0.1 degrees)
pitch	1	2	2	A	(0.1 degrees)
roll	1	2	2	A	(0.1 degrees)
temperature	1	2	2	A	(0.01 degrees C)
pressure	1	2	2	A	(counts)
Checksum	1	2	2	A	sum of bytes plus base (0xa596)
Keyword(8112)	1	2	2	B	
Sample Id	1	2	2	B	1 - number of samples in burst
Velocity	3	2	6	B	(0.1 mm/sec)
Signal Strength	3	1	3	B	(counts, where 0.43 dB/count)
Correlation Coefficient	3	1	3	B	(0 to 100, where > 70 is considered ok)
Checksum	1	2	2	B	sum of bytes plus base (0xa596)
YSI_temps	5	2	10	*	Thermistor counts from YSIs
Total bytes/record:			56		

The DopBeam data were logged in 45000225 byte binary files. Even and odd-hours were logged in different directories and each month was stored in its designated directory. Each file is named Hddhmm.DAT, where dd, hh and mm represents the day of the month, hour of the day and the minute at the start of the burst. A 50 byte header precedes the profile data and contains:

HC2: (identifier)  
 125 (the number of bins)  
 120000 (the number of profiles in the file)  
 500 (the number of timing rams, which defines the time between profiles)  
 150 (the minimum amplitude, defines that data < 150 are mapped to zero)  
 250 (the maximum amplitude, defines that data > 250 are mapped to 255)  
 175 (the DC offset to 1V for off-board cos/sine - irrelevant)  
 timestamp (such as 06/23/ 11:57:02)

Each field is separated by a colon. The data follows in 3 bytes per bin (amplitude, cosine and sine of the acoustic signal for each bin). The beginning of each profile is coded so that all three fields are 0xff. This flag (0xfffff) should occur every 125\*3 bytes. A time stamp follows the data, such as 06/23 12:02:22, noting the time when the profile was completed.

## Data Summary Files

There are two Matlab files summarizing the ADV, thermistor and Seagauge data, **hycode2000** and **hycode2001**. Each file contains the following variables:

tdoy, mmon, mday, mhr - mean year day, month, day and hour (GMT) of each burst to aid in loading events  
I - the mean of acoustic doppler signal strength (I) (dB)  
I\_std - the standard deviation of I within each half-hour burst (dB)  
Iw - the covariance of I with vertical velocity, w (dB/m/s)  
Tb\_xz, Tb\_yz - eastward, northward bottom-stress (PA)  
depth - water depth (Seagauge pressure + 4.3) (m)  
north, east, up - northward, eastward and upward current at each ADV (m/s)  
eps23 - dissipation<sup>2/3</sup> (W/kg) (from vertical velocity of each ADV)  
fbar - mean frequency in the wave band (Hz)  
press\_a - burst average of pressure above the ADV OP<sub>A</sub> pressure sensor (m)  
press\_a\_std - standard deviation within burst of ADV OP<sub>A</sub> pressure sensor (m)  
saln\_sg - salinity reported from the Seagauge (PSU)  
speed\_u, speed\_v -  $\langle |u| \cdot u \rangle$  (m<sup>2</sup>/s<sup>2</sup>)  
temp\_sg - mean temperature from the Seagauge (degC)  
temp\_a, temp\_a\_std - mean, standard deviation of temperature from ADV OP<sub>A</sub> (deg C)  
urms - wave-induced bottom orbital velocity (m/s) from each ADV  
var\_uu - variance of eastward current at each sensor (m<sup>2</sup>/s<sup>2</sup>)  
var\_vv - variance of northward current at each sensor (m<sup>2</sup>/s<sup>2</sup>)  
var\_ww - variance of upward current at each sensor (m<sup>2</sup>/s<sup>2</sup>)  
wave\_angle - wave direction (0=from east, + is north of east) (degrees),  
from horizontal velocities of each ADV  
wave\_height\_sg - the significant wave height (m), as computed by Seagauge software,  
representing the highest 1/3 of the waves  
wave\_period\_sg - the period corresponding to the frequency with the highest variance,  
as computed by Seagauge software  
ysi - mean temperature approximately 10 cm from the velocity sensing volume  
of each ADV (deg C)  
ysi\_std - the standard deviation within each burst of the ysi temperatures (deg C)  
z - height of the velocity sensing volumes above a nominal bottom (m)  
z\_sg - the height of the Seagauge sensors above a nominal bottom (m)

For 2001, **hycode2001** also contains the following data:

Iamp - the mean signal strength of each bin during the five minute burst  
Ivar - the variance in the signal strength  
WI - the covariance of vertical velocity with signal strength  
Wvar - velocity variance (m<sup>2</sup>/s<sup>2</sup>) in each bin  
Zn - the nominal height above bottom of each bin  
nz - bins selected to be free of multipath reflections  
tdoy\_db - the year in GMT  
tdoy\_sg - the year day of the Seagauge data

## Processed Burst Data Files

For the **ADV** and **YSI** data, files are archived with file names Nmmddhh.mat, where N is

a - ADV OP<sub>A</sub> velocity data

b - ADV OP<sub>B</sub> velocity data

Y - YSI thermistor data

and mm,dd and hh, represent month, day and hour of the mean burst averaged time (GMT).

Velocity data can be brought into Matlab by loading the data file for each sensor and then running the Matlab scripts loadopa.m and loadopb.m to clean up the data and convert the units to m/s (Appendix A.) This provides 9060 samples of u, v and w, which was recorded at 5 Hz. The ysi files contain temperature (deg C)×100.

**ADV OP<sub>A</sub> pressure** (m) and **temperature** (deg C) data, at approximately 3.9 mab, are stored in files named ammdhh\_pt.mat, as above.

**Seagauge tide** data are stored in files jul2000.tid, sep2000.tid and jun2001.tid containing:

sample id, month, day, hour, minute, second, pressure (psia),

temperature (deg C), conductivity (S/m) and salinity (PSU)

time is GMT.

**Seagauge wave** data are stored in files jul2000.wb, sep2000.wb and jun2001.wb in the wave burst data file format, as described in the Seagauge Wave and Tide Recorder Operating Manual. These data are also archived as Matlab files (jul\_wb.mat, sep\_wb.mat and jun01\_wb.mat) containing:

tdoy\_wv = Year day of the burst (GMT)

pressure = 256 pressure records for each time (m)

depth = mean water depth of each record (m)

The jul\_wb.mat and sep\_wb.mat records are 1 Hz. The jun01\_wb.mat pressure records are 4 Hz.

The processed **vertical velocity** from the **DopBeam** are stored in files:

Immdhh - containing signal strength

vmmddhh - containing vertical velocity averaged over 40 samples,  
providing data at approximately 9 Hz (375Hz/40) for all 125 bins

vcmmdhh - containing the velocity, above, which has been cleaned up  
by interpolating over all data which are more than four times  
the burst standard deviation away from the burst averaged velocity.

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## VIII. ACKNOWLEDGMENTS

Special thanks to the crew of the R/V Endeavor, Derek Manov, Frank Spada, Dave Sigurdson and Matt Gould for their support in the deployments of the tripods. Also, we thank Andrew Waterbury, Paul Dombrowski and Scott Birdwhistell for their support in the assembly of the tripod and instrumentation. We are also grateful for the technical support provided by Albert Williams, 3rd, and Eugene Terray in the development of the data loggers. And for the anchoring, we thank the dive team from Rutgers University, in particular the support from Rose Petracca. For the use of the Seagauge sensors, we thank Craig Marquette.

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<b>16. Abstract (Limit: 200 words)</b> <p>A tall tripod equipped with two acoustic Doppler velocimeters (ADV's) was deployed at a water depth of 15 m off the coast of New Jersey near the LEO-15 site. Sensors were co-located near the bottom to provide good estimates of Reynolds stress. Thermistors were located within several centimeters of the velocity sample volume to provide simultaneously sampled estimates of turbulent temperature variance and vertical temperature flux. One of the ADV's was equipped with a pressure and a temperature sensor. A wave/tide gauge was placed at 4 meters above bottom. The instruments were deployed late July through early December of 2000 and late June through early August of 2001. For the 2001 deployment, a single beam acoustic Doppler velocity sensor (DopBeam) was added to measure high frequency vertical velocity variance and echo intensity within the bottom boundary layer.</p> <p>A second tripod was deployed nearby and was equipped with an array of LISST sensors and an MSCAT.</p> <p>The purpose of this report is to document the instrumentation and deployment of the tripods and to document the tall tripod data by providing a description of the processing and data formats, time-series summaries of the burst averaged data along with preliminary analyses.</p>			
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